PETROLEUM DEVELOPMENT AND TECHNOLOGY

1940

PETROLEUM DIVISION

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1940

PETROLEUM DIVISION

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Geophysical Studies in California. By F. E. Vaughan. See Bulletin published by California Division of Mines: Geologic Formations and Economic Development of California Oil and Gas Fields.

The Eykometer, A New Device for Measurement of the Yield Point of Clay Suspensions and Oil-well Drilling Muds. By A. G. Stern. U. S. Bureau of Mines *R.I.* 3495.

Mixing of Gases in Porous Media. By R. Ducker and R. L. Huntington See *Natural Gas Proceedings,* American Gas Association (1940).

Properties of a Petroleum Reservoir Liquid and Its Residua with Application of the Data to Production Problems. By Kenneth Eilerts, R. V. Smith and A. B. Cook. U. S. Bureau of Mines. *R.I.* 3474.

Valuation of Oil and Natural Gas Properties as Distinguished from Mines. By L. F. Terry. See *Mining and Metallurgy,* May 1940.

Economic Aspects of Oil-field Exploitation in Colombia. By E. Ospina-Racines. See *World Petroleum,* March 1939.

Place of the Oil Industry in the National Economy. By John D. Gill and Edward T. Knight. See *Bulletin* Robert Morris Associates, April 1940; also *Mining and Metallurgy,* Aug. 1940.

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Subsurface Trespass. By M. Kline. See American Bar Association, Section of Mineral Law, 1939, special pamphlet.

PLANS OF THE PETROLEUM DIVISION FOR 1940–1941

It is becoming continually more difficult for engineers engaged in the production of oil and gas to keep up with the rapidly advancing technology in this field. The Institute's Petroleum Division has, in a large measure, the responsibility of providing facilities through which its membership can keep informed on important technical developments. The publications of the Division are the most important of these facilities, inasmuch as they furnish to each member a record of technical progress for study and reference. For several years the number of papers submitted to the Division's Papers and Programs Committee has been continually increasing, and as a consequence the standards of the technical publications have been raised materially. Even so, the volume of acceptable papers considered by the Division is increasing at such a rate that soon the facilities for publication will be taxed to the limit, and plans must soon be made for more frequent issue of the Division's publications. Of course, a more ambitious program of publication cannot be put into effect immediately and should not be put into effect until the interests of the membership demand it; but it behooves the Division and its officers to take a long range view of the problem, and to establish and follow a fundamentally sound policy. In maintaining such a continuity of the Division's activities from year to year, the work of the Institute's Assistant Secretary assigned to the Petroleum Division has been most helpful.

Early in 1940, the East Texas Section was authorized by the Board of Directors of the Institute. Inasmuch as the primary interest of the members of this locality is in petroleum, the East Texas Section is expected to contribute substantially to the activity of the Petroleum Division.

Preparations are being made for technical programs of the Petroleum Division meetings, which will be held October 17–18 in Los Angeles, October 24–26 in Tulsa, and in New York at the time of the Institute's Annual meeting in February 1941.

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In 1936 the Institute established the Anthony F. Lucas Gold Medal, to be awarded from time to time "for distinguished achievement in improving the technique and practice of finding and producing petroleum." These awards are sponsored by the Petroleum Division.

Captain Lucas was a pioneer in the oil industry, one of the early wildcatters and a leading mining and petroleum engineer. He was famous as the discoverer of Spindletop. He became a member of the Institute in 1895 and in 1913 was the first Chairman of the Petroleum and Gas Committee of the Institute, the forerunner of the present Petroleum Division. He also headed the Committee in 1914, 1917 and 1918.

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Chapter I. Production Engineering

A Résumé of the Application of Gravel Packing to Oil Wells in California

By W. A. Clark*

(San Antonio Meeting, October 1938)

The production of sand in an oil well increases operating costs because of abnormal wear in subsurface equipment, the necessity for frequent cleanouts, and the need for a means of disposing of the sand. Moreover, removal of sand from the zone can bring about the creation of cavities from which bodies of formation, sand or shale, may slough into the hole, endangering the shutoff, impeding production or collapsing the liner. The procedure known as gravel packing is attracting attention as a means of controlling these factors and contributing to the productive life of a well. That gravel packing is now substantially beyond the preliminary stage on the Pacific Coast is reflected in the 191,000 bbl. of oil produced monthly by the 66 gravel-packed wells in 11 different producing sectors.

Reasons for Gravel Packing

Gravel packing, if properly carried out, can be expected to provide the following benefits:

1. Prevent the movement of sand and thus eliminate sand production and sand fills, and prevent the formation of cavities.

2. Provide a practical, relatively inexpensive, large-diameter hole, which will provide well-known theoretical advantages.

3. Support the walls of the hole by completely filling the space between the liner and the formation, regardless of its irregularities, and afford a support for liners.

4. Provide for more efficient pumping operations in wells by: (*a*) possibly utilizing the gravel as a gas trap in pumping gaseous fluids, (*b*) allowing deep submergence of the pump into the oil zone.

In a conventional well—that is, where the liner is set in an open hole—even though perforation sizes are chosen according to known rules based on analysis of sand grains from samples from the zone, there is likely to be some production of sand. This may be due to the miscalculation of

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* Petroleum Engineer, The Texas Company (Calif.), Fellows, California.

the slot size, or to the irregular shapes of the sand grains. Also, abrasion by fine sand during initial flow can enlarge the slots and destroy the function of the size used. Moreover, there is some reluctance on the part of many operators to set perforated pipe containing slot sizes based on sand-grain size in low-gravity oil zones. This is particularly true if the sand is fine-grained, because of the belief that oil production would be impaired.

Methods of Installing Gravel Pack

It is at once apparent that several factors that are not applicable in completing wells in the conventional fashion must be taken into consideration, among them being: (1) size of hole to be used (that is, what thickness of gravel sheath is desirable); (2) size of gravel; (3) choice of circulating fluid and its effect within the sheath, and what means will be necessary to remove it; (4) the type and size of liner and perforations therein; and (5) the best means of installing the gravel in the annular space between the liner and the hole.

At first liners were packed in a 20-in. hole, but later the diameter was reduced to 15 in. without loss of effective sand screening. Liner diameters were either 5 or 6⅝ in., depending upon well capacity.

At the outset there was no scientific choice of gravel diameters. Several months after the initial use of the operation, calculations by E. L. Davis[1] and experiments by C. J. Coberly and E. M. Wagner[2] brought out the fact that to impose sand bridging upon gravel interstices the gravel size should be equal in diameter to 12 or 13 times the size of the sand grains at the 10 per cent point on the cumulative grading curve of the sand to be produced. After this rule was established, gravels were chosen on this basis, and resulted in a general reduction in gravel diameters from ½ to ⅝ in. to as small as ⅒ to ⅛ inch.

Investigation of circulating fluids with which to place the gravel has disclosed the fact that the properties of a 4 per cent mixture of bentonite and water, compared to native muds, will minimize adherence to the gravel and lay down a thin mud cake that is practically impervious to fluid loss but that will easily slough or wash off when flow is reversed. Where a bentonite fluid has not been available, many wells have been successfully packed by using various native muds thinned to a low viscosity.

Liners used in the first gravel-packed wells were flush-jointed, but very soon collared pipe came into use. Liners in these later wells were generally centered in the hole by means of spring guides, so that they would be surrounded by a sheath of gravel of uniform thickness.

---

[1] E. L. Davis: Assistant Chief Petroleum Engineer, The Texas Company (California).

[2] C. J. Coberly and E. M. Wagner: Some Considerations in the Selection and Installation of Gravel Pack in Oil Wells. A.I.M.E. *Tech. Pub.* 960 (*Petr. Tech.* Aug. 1938).

Perforations in the liner are chosen on the basis of previous field practice and on the basis of the diameter of the gravels to be used. That is, the perforations are only sufficiently narrow to retain the individual pebbles. Slots thus chosen are satisfactory, provided the liner is centered in the hole and surrounded by a gravel sheath of uniform thickness.

Several methods of installing the liner and gravel have been applied:

1. A liner containing a suitable conduit formed by blanking the perforations with cement, or by means of a wash pipe, is hung at the bottom of the hole. The suspending string is packed off at the surface. Gravel is then alternately dribbled or pumped into the annular space between the casing and the suspending string and washed down the hole by reversed circulation.

2. The gravel is placed, or dumped, into the open hole, filling it to the shoe of the primary casing. The perforated casing is washed, jetted or otherwise forced through the gravel to the bottom of the hole.

3. The gravel is placed in the open hole and the well is produced through the gravel alone without the use of a perforated string.

4. The liner with a basket at its bottom end is hung above the shoe of the primary casing. The annular space between the casing and the liner is filled with an amount of gravel calculated to fill the zone, and the liner and gravel are lowered to bottom.

Several other methods of gravel packing have been proposed, which appear to be theoretically possible, but they are believed to be less practical than the methods described above, which have been demonstrated to be feasible, by actual test.

The method first mentioned is used most frequently. This method is greatly facilitated by the use of a pressure mixing device such as is provided by the machine known as the Layne Graveler. In this apparatus the gravel is mixed directly with the circulating fluid and pumped continuously into the well.

Of the other methods that have been tried, the one in which the liner is jetted through the gravel has been successfully accomplished several times. With this procedure, a shoe formed in the shape of a jet is attached to the bottom of the liner.

The method of lowering the gravel and liner together to the bottom of the hole was successfully carried out in one well where a small volume of gravel was used. It was difficult to get the liner and gravel to fall at all, because of the frictional drag of the gravel through the collars in the primary string, until a sufficient amount of drill pipe had been added to provide enough weight to overcome the resistance encountered.

The production of oil through a hole filled with gravel without the use of a perforated string was attempted once in the San Joaquin Valley and once in the Coastal area, but was unsatisfactory in both tests. Obviously, this gravel-packing method would be applicable only in wells of high formation pressure and probably would not succeed then unless the gravel were held in place.

Gravel packing adds to the normal cost of drilling. Extra drilling costs due to gravel packing are compared in Table 1, which shows average extra costs for several wells in different fields.

TABLE 1.—*Average Additional Cost per Well of Gravel Packing*
(Time cost used is taken at the rate of $350 per day)

Field	Average Depth, Ft.	Average Thickness of Zone, Ft.	Extra Drilling Days	Total Time Cost	Estimated Material Cost	Total Extra Cost per Well
Mount Poso	1,250	30	2	$ 700	$ 350	$1,050
Maricopa	3,000	120	2	700	1,300	2,000
Kern Front	2,100	300	2	700	1,450	2,150
Wilmington	3,300	400	5	1,750	1,500	3,250
Huntington Beach[a]	3,800	150	9	3,150	1,500	4,650

[a] These were the first gravel-packed wells in the Los Angeles Basin. The high cost shown is attributed to necessary experimental work.

EXTENT OF INSTALLATION

During the past 15 months, over 65 wells have been completed with gravel-packed liners in the state of California. Of these, the operation was applied to 32 in the San Joaquin Valley, 30 in the Los Angeles Basin, and 4 in the Coastal area. The amount of zone that has been packed ranges from 25 to 666 ft. at depths from 1100 to 6700 ft. The gravity of oil produced ranges from 13.5° to 25° A.P.I. gravity. The procedure has been applied to low-pressure zones containing from as little as 250 ft. of fluid, up to and including flowing wells. A summary of the number of wells that have been gravel-packed in the various fields in California is given in Table 2.

TABLE 2.—*Extent of Application of Gravel Packing to California Wells*

Field	Number of Wells Gravel-Packed	Depth Range, Ft.	Thickness of Producing Zone, Ft.	Sand Fineness, Average Cumulative 10 Per Cent Point on Grading Curve, In.	Diameter of Gravel, In.	Gravity of Oil, A.P.I.
Kern Front area	8	2050–2813	80–340	0.06	½	13.5°–13.9°
Lost Hills	6	1100–1250	15–120	0.008	¼	13.9°–14.2°
Midway-Maricopa	13	2900–3270	40–130	0.045–0.025	⅜	22.0°–23.0°
Mount Poso	2	1250	30	0.02	⅛	16.5°–17.0°
Wilmington	24	2905–3647	220–666	0.0136	1/10	14.3°–18.4°
Torrance	2	3628	400			14.2°
Huntington Beach	4	3620–4030	80–225	0.026		21.0°–25.0°
Miscellaneous	7	3000–6662	20–200			

EFFECT OF GRAVEL PACKING ON PRODUCTION

Based on a study of data relative to completions and subsequent production, it has been found that current production rates from pumping wells that are gravel-packed equal, and occasionally exceed, in volume the usual type of well. The desirability of gravel-packing flowing wells is disputed by some because of small potential rates that have been recorded in a few wells at Wilmington. However, this lower rate could be explained by variations in the productivity of the zone.

Cumulative production from gravel-packing wells is, as a general rule, greater than that from conventional types over the same production period. This is caused by deferred or lost production in the latter wells due to downtime for pulling and bailing.

EFFECT OF GRAVEL PACKING ON SAND PRODUCTION

It has been found in several fields, even in those containing low fluid levels, that the initial bailing time prior to the production of graveled wells amounts to only 20 per cent of the time required to bail all the loose sand from the conventional well. Bailing necessary after completion and during the production life of graveled wells appear to require no more than 40 per cent and as little as 5 per cent of the time required to bail conventional wells.

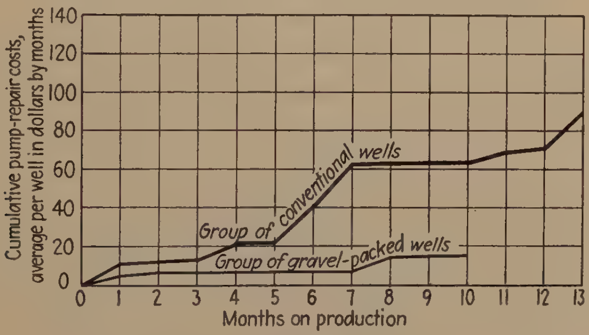

FIG. 1.—PUMP-REPAIR COSTS.

Using lead-line cuts for comparison between conventional and gravel-packed wells, it appeared that less sand was produced with the oil in the gravel-packed well than in the conventional well. This was particularly evident in wells that had a size of gravel correctly chosen to conform with the size of sand grain. In the latter wells the only sediment produced consisted not of sand but of silt, to the extent of less than 1 per cent. Since lead-line cuts are taken irregularly in periods of a day or a week apart, they are unsatisfactory for comparative purposes. A more accurate method of comparing sand production is the measurement of the sand produced. At Lost Hills, for example, an area of very fine, running sand, a gravel-packed well was completed with a production of 67 bbl. per day of oil and 47 bbl. per day of sand. The sand production declined in 15 days to 3 bbl. per day and in 30 days to 0.5 bbl. per day. An offset well conventionally completed with a comparable fluid rate produced sand for over a month in volumes as high as 100 bbl. per day.

Since pump wear is proportional to the amount of sand produced, comparison of costs of pump replacements should give a fairly accurate picture of the efficiency of gravel toward retaining sand. Figs. 1 and 2 show curves of cumulative pump-repair costs expended on two types of wells on two producing properties. Fig. 1 shows that in a 10-month period the pump-repair cost for the average conventional well was $63, whereas that of the average gravel-packed well was but $15. Fig. 2 shows that in nine months the lowest-cost group of gravel-packed wells on another property averaged $130 per well as against another gravel-packed group (which had production rates more comparable with those of the conventional wells), which averaged $295 per well. These are compared with the average well-pump cost of a group of conventional wells that amounted to $1100 per well.

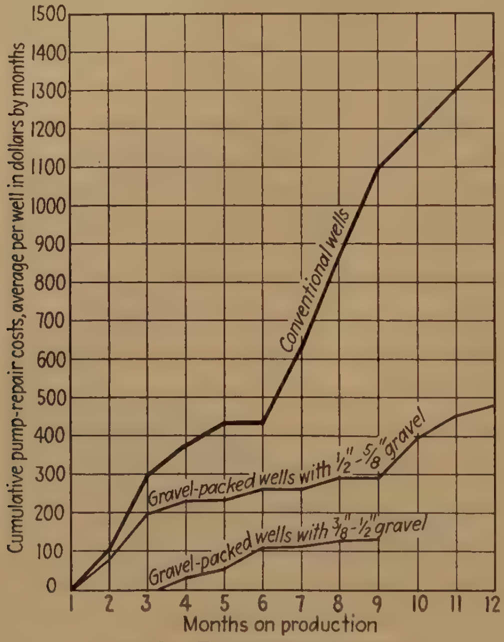

FIG. 2.—PUMP-REPAIR COSTS.

A third means of comparing sand production is to compare maintenance costs due to pulling and bailing. Fig. 3 shows comparative curves of cumulative downtime due to these causes on a property in the San

Joaquin Valley. Assuming that the labor cost of pulling and bailing will in general be proportionate to the downtime due to those causes, it can be seen from Fig. 3 that the maintenance cost of gravel-packed wells on this property is but 26.5 per cent of that of conventional wells. This calculation does not include any savings on equipment replacement.

Another example of comparative maintenance costs can be made in the Wilmington field. The offset wells to a group of gravel-packed wells, all pumping, had an average cost due to pulling and bailing of $4800 per well during a productive period of 202 days following completion. During a similar average productive period, the graveled wells averaged a maintenance cost of but $550 per well.

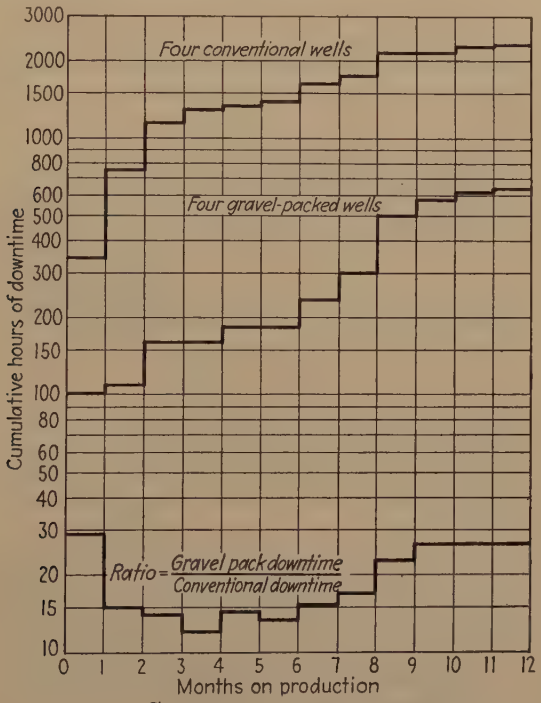

FIG. 3.—COMPARATIVE DOWNTIME CURVES.

In neither of the two examples given above was there included in the costs the value of production deferred or lost during the period of downtime. This item is important in areas of competitive production, in fields of receding fluid levels, or in marginal properties in the path of encroaching edge waters.

CONCLUSIONS

1. Gravel packing should be given consideration wherever oil wells are drilled in areas containing zones of unconsolidated or moving sands.

2. The mechanics of installing a gravel sheath around a liner in the bottom of a well are feasible and practical. It is relatively inexpensive, the extra cost being as a rule not more than 10 per cent of the total cost of drilling the well.

3. Field results have proved that current production rates of gravel-packed wells are more sustained than those of wells conventionally completed, except in a few instances as noted. Reduction of downtime caused by sanding conditions results in a cumulative production that favors the former type.

4. Indicated reduction in sand production will result in lessened maintenance and equipment replacement costs. Savings thus effected will pay for the extra cost of the gravel pack within a period of one to three years, and yield a considerable profit thereafter. This does not take into account possible intangible savings that may result from the prevention of collapsed oil strings.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance rendered by the personnel of the Producing Department of The Texas Company, and in particular that of E. L. Davis, W. W. Robinson and R. F. Cory; also, the helpfulness of Mr. C. J. Dean, of the General Petroleum Corporation, who supplied various data on wells at Wilmington.

DISCUSSION

(*E. P. Hayes presiding*)

J. E. ECKEL,* Houston, Tex.—Have you had any experience in placing gravel with acid-soluble mud as the carrying medium? What is your opinion of the feasibility of this method?

W. A. CLARK.—In the last five or six wells gravel-packed, the fluid with which the gravel was placed contained 2 to 3 per cent ground calcium carbonate. Three of these wells were treated with acid after the gravel was placed and prior to production. We are not prepared to report comparative results because of the few wells treated. There is no difficulty in using this addition to the operation except that one liner was inadvertently withdrawn from the hole owing to the sticking of a swab while the well was being washed after the acid was placed.

J. E. ECKEL.—Does the degree of fineness of the gravel have any effect on the removal of bentonitic mud?

W. A. CLARK.—Reported results of subsequent production from wells in the Wilmington field where gravel of $\frac{1}{10}$ to $\frac{1}{8}$ in. was used indicate that mud fluid remains in a pack of very fine gravel.

J. E. ECKEL.—Is there any reason why gravel packing would not be successful in extremely high-gravity wells?

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* Humble Oil and Refining Co

W. A. Clark.—I see no reason. On the contrary, gravel packing should be more feasible with high-gravity oil because the gravel should be more easily cleaned of mud. In California most of the high-gravity fields contain firm or hard formations, which eliminate the necessity for gravel packing.

J. E. Eckel.—In the wells you mentioned, which were graveled by rotating the liner into gravel, was it difficult to keep the liner centered in the gravel pack?

W. A. Clark.—We have no means of knowing whether or not the liner was centered in the gravel after the operation was completed. In one case, at least, we are certain it was not, because the well subsequently produced considerable sand; the slot size was large, 140 mesh, and had not been selected in relation to the effective grain size of the sand.

E. M. Wagner,* Huntington Park, Calif.—The results cited by Mr. Clark show that gravel packing can be used successfully to control sand production in areas where formation is loose or poorly consolidated.

One important point is the selection of the diameter of liner to be used in the gravel pack. In many wells pumping cannot be efficiently carried on because the liner is too small in relation to the oil and gas production to permit running gas anchors and pumps of optimum size. As a consequence, the production desired often cannot be obtained. Tests have shown that an inch thickness of gravel, of the proper size in relation to the effective grain diameter of the formation, is ample to completely retain the producing sand. With these facts in mind, ordinarily it would seem best to set the largest liner that can be run through the water string, under-reaming the hole in the producing zone so that a practical depth of gravel, say a minimum of 3 in. on a side, can be placed around the liner. Occasionally, this practice might result in a liner of excessive size. In such a case, the selection of the liner size could be based on the gas anchor and pump that are to be used.

Some methods of placing gravel limit the liner size to something less than the largest size that can be run through the water string. This may result in a serious limitation on pumping efficiency. Methods of placing gravel that do not have such a limitation on liner size will therefore probably result in better pumping wells.

The opinion is stated that irregularity of grain shape is a factor contributing to sand production in slotted and screen casing. On the contrary, this is a factor contributing to the stability of the sand bridge formed, as shown by tests with steel balls and sand grains of approximately the same size.[3] The most probable reason for sand production through slotted or screen casing is that the mesh is too great for the particular sand in question. In such a case, there is danger of sand cutting, which would make conditions progressively worse.

It is presumed that the gravel-packed wells that produced sand in considerable quantity, assuming that the gravel envelope was completely formed, were some of the earlier wells, which were packed with large gravel not selected in relation to the effective grain size of the formation sand. Where gravel of the proper size is used, and the envelope is complete, sand production should be very low. After the initial bailing, when the well is first put on production, bailing should practically never be necessary. Small amounts of fines, such as silt, may be continuously produced, as pointed out by Mr. Clark.

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* Kobe, Inc.

[3] C. J. Coberly: Selection of Screen Openings for Unconsolidated Sands. Amer. Petr. Inst., Drill. and Prod. Practice (1937) 189–201.

Mr. Clark shows that cement and shale cuttings that are washed against the slots during placing of the gravel tend to plug the slots in the liner. Possibly less trouble from this source might be experienced if the gravel were placed from the lower end of the liner through a wash tube, circulation being in the usual direction. Practical difficulties of carrying on such a method of placement might offset any advantages to be gained. As far as is known by the writer, no gravel packing has been done in this manner, although it has been suggested.

Multistage Stabilization of Crude

By H. S. Gibson*

(New York Meeting, February 1939)

A process that has come to be known locally as "multistage stabilization" has been developed in the Haft Kel field of the Anglo-Iranian Oil Co. in southwest Iran, for the recovery of casinghead gasoline. It consists in releasing the dissolved gases from the crude by stages, a practice common in many fields, but which, so far as is known, has nowhere been carried to the extent to which it is employed in Iran. It has been in use there for nearly nine years, during which time some 200 million barrels of crude have been handled by the process. This process of gasoline retention consists in preventing the greater part of the casinghead gasoline hydrocarbons (the butanes and pentanes) from ever leaving the crude, instead of allowing them to be vaporized and then recovered from the lighter gases by the usual compression or absorption processes. Its efficiency is fully equal to that obtained by the absorption process; its disadvantage is that it increases the quantities of ethane and propane in the crude sent to the refinery, but with the growing demand for propane this drawback is vanishing.

When casinghead gasoline is recovered as a separate liquid in the Iranian fields, it is blended with the crude, as the only outlet is through the refinery, and the crude-oil pipe line offers the cheapest means of transportation. It is under these conditions that the retention of the butanes and pentanes in the crude by multistage stabilization is a most attractive process, possessing as it does the following advantages: (1) extreme simplicity, (2) low first cost, (3) easy installation, (4) practically 100 per cent operating-time efficiency, (5) no operators required, (6) no water or other services required, (7) negligible maintenance, (8) once established, very little routine testing is necessary.

The one essential for reasonably efficient multistage stabilization is that the flowing pressures of the wells should be relatively high; i.e., they should not be less than about one-third the saturation pressure of the crude in the reservoir. This is a very general statement, of course, and much depends on the type of crude and its temperature.

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* Anglo-Iranian Oil Co. Ltd., London, England.

Multistage stabilization is so named because the gas is separated from the oil in a number of stages, in each of which the oil and gas are in equilibrium.

The first experiments were made in 1929; they culminated in November of that year in the construction of a pilot plant with a capacity of 300 bbl. of crude per hour. The first full-scale plant, of 40,000 bbl. per day capacity, was completed and put into operation in March 1930. No gas analyses were then available, and there was no information regarding the behavior of gases in solution in crude at the higher pressures. The original operating pressures and the number of stages of separation were estimated on the basis of the simple gas laws. These indicated that six stages operating between a flowhead pressure of 500 lb. and a final pressure of 10 lb. per sq. in. gauge would give a good efficiency of gasoline retention, and that the operating pressures should be such that equal volumes of gas, measured at their respective pressures of separation, should be removed from each stage.

The value of 10 lb. per sq. in. at 80° F. (this temperature is taken as the standard in southwest Iran, as it is approximately the average working temperature) was chosen as the final pressure, on the basis that if the whole of the casinghead gasoline could be recovered from the Haft Kel single-flash flow-tank gas by the 250-lb. compression process it would, when added to the crude, give the latter a vapor pressure of approximately that amount. "Ten-pound crude" is now a standard product delivered to the Abadan refinery.

When the Podbielniak apparatus for the low-temperature fractionation of gases became available, the process was examined in detail, and it was found, of course, that at the higher pressures there is a considerable deviation from Raoult's law. This did not affect the operation of the process at Haft Kel very much, however, because the first-stage pressure is more or less decided by the flowing pressures of the wells.

With the information thus obtained an attempt was made to develop a method by which the optimum pressures of separation for the retention of butanes and pentanes in crude could be calculated, but it was concluded that a general solution would depend upon far too many variables to be sufficiently accurate, and that the most satisfactory procedure would be to determine the pressures for each field by trial and error. The method employed at Haft Kel is to obtain the K values for that particular crude over the limited pressure and temperature ranges required, and from these calculate the pressures that fulfil the required conditions.

So far the multistage stabilization process has been used only at Haft Kel, therefore this paper deals with it only in connection with that field, but tests have shown that it will be equally suitable for the new field of Gach Saran, and a unit with a capacity of 150,000 bbl. per day is now being installed there.

OPERATING CONDITIONS AND RESULTS AT HAFT KEL

The effect of separating gas from crude by stages is now well known and needs no description. It can be shown by simple calculation that the maximum efficiency of retention of one of the heavier gases is obtained when the amount of that gas removed in each stage is a constant proportion of that available in the stage. It is on this basic condition of the process that the operating pressures at Haft Kel have been determined.

If the gases obeyed the simple gas laws, each gas present would require the same pressures for maximum retention, but, as their solubility coefficients (Bunsen's coefficients) are different functions of total pressure, each component demands a different series of pressures for its maximum retention. Fortunately, the differences between the butanes and pentanes are not great and their effects are not measurable in the final result. For the control of the process at Haft Kel normal butane is used as the standard of reference.

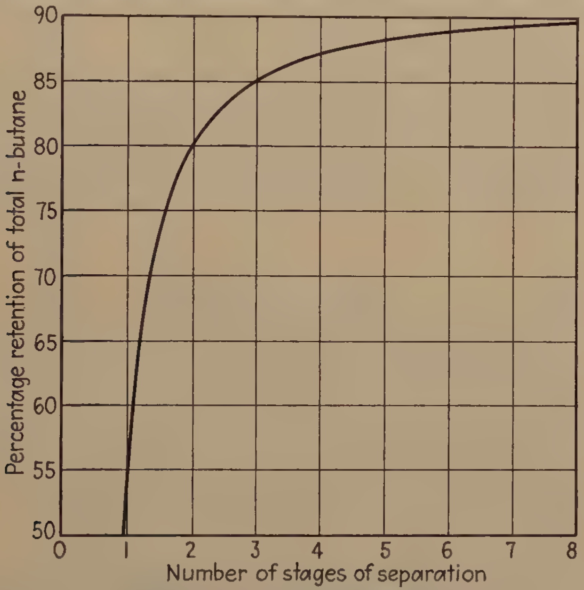

FIG. 1.—PERCENTAGE RETENTION OF TOTAL NORMAL BUTANE PLOTTED AGAINST NUMBER OF STAGES EMPLOYED.

Number of Stages of Separation

This is in many ways the most important question in multistage stabilization. In Fig. 1 a curve is given showing the percentage of the total normal butane retained at 80° F. and a final pressure of 10 lb. per sq. in. gauge plotted against number of stages employed. This curve has been obtained by calculation in order to obtain smooth uniform values, and it is in general agreement with experience up to six stages.

As mentioned earlier, six stages are employed to a final pressure of 10 lb. per sq. in. gauge, although from this curve it is clear that four stages would give good results and that the improvement between five and six is very small. The reason for six stages is that it allows for considerable variation in the operating pressures without measurable effect on the final results. There is no difficulty in the determination of the correct pressures to within sufficiently close limits, or of their application, but very considerable deviations from the optimum take place as a result of temperature variations.

If the pressures of some of the separators deviate appreciably from the optimum, the chain of separators can be imagined to consist of two portions, one in which the pressure interval is narrowed (i.e., has more stages), and the other in which the intervals are increased (which is equivalent to reducing the number of stages). With a total of five stages, we can imagine that we are then really working with the average of four and six, and the slope down to four is distinctly steeper than that up to six. With six stages, on the other hand, the slopes on either side are almost equal, with the result that the operating pressures can be changed appreciably from their correct values without unduly affecting the results.

Operating Pressures

With full freedom of selection, the first stage of separation at Haft Kel would be carried out in the region of 750 lb. per sq. in. Although a few of the wells approach this, the flowing pressures of the majority lie between 500 and 600-lb. gauge, at a constant temperature of 105° F. The first stage of separation is therefore carried out in separators sited as closely as possible to the wellheads in order to obtain the highest possible pressure. The use of six stages helps to counterbalance the loss of efficiency that results from the lower first-stage pressures.

Although the question does not arise at Haft Kel, it may be necessary in high-pressure fields to take into consideration the reversals of the K values of the butanes and pentanes which occur between approximately 700 and 1000 lb. per sq. in. In such cases there is a maximum pressure of separation which should not be exceeded, otherwise larger quantities than need be of the heavier gases are removed.

At the standard temperature of 80° F. the operating pressures of the five stages of separation that follow the wellhead separators are, respectively, 218, 102, 55, 34 and 25 lb. per sq. in. absolute. Although 80° F. is the average, the temperature of the oil being handled varies between 140° and 40° F., which are the extremes of summer and winter. The rise of temperature reduces the efficiency of multistage stabilization considerably, owing to the fact that the solubility coefficients of the heavier gases are reduced to a greater proportionate extent than those of the lighter gases. But for this it would be possible to regulate the pressures according to the temperature and maintain constant efficiency.

It was stated earlier that the final pressure of 10 lb. per sq. in. at 80° F. was selected because it approximates the vapor pressure of the crude with 250-lb. compression gasoline added. Abadan refinery is about 125 miles from the Haft Kel field, and the oil that is produced and processed in the cool of the night at about 80° F. may arrive there in the middle of a summer day at 140° F., with a vapor pressure of nearly 30 lb. per sq. in. gauge. The pipe-line boosting stations and the refinery have arranged their plant so that they can handle oil of this vapor pressure without any difficulty, but it is the maximum to which they are at present prepared to go. The crude dispatched to the refinery is therefore separated to final pressure which gives approximately a vapor pressure of 10-lb. gauge at 80° F.; i.e., at 140° F. the final separator pressure is 43 lb. abs., in order to offset as far as possible the loss of efficiency due to the higher temperature. The operating pressures of the other stages are also varied with temperature (with the exception of the first stage at the wellheads) in order to keep them relatively correct. Fig. 2 shows the relations between temperature and pressures; actually these should be slightly curved, but to simplify the control an average straight-line relationship is used, as it is sufficiently accurate for all practical

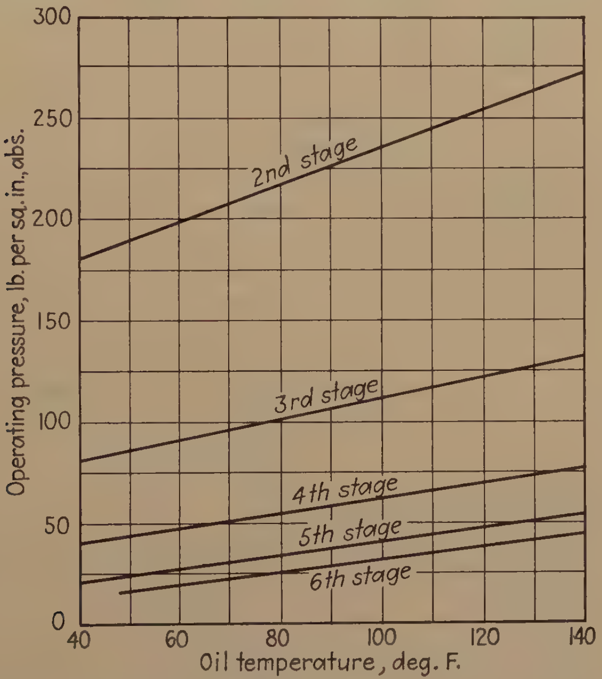

FIG. 2.—EFFECTS OF OPERATING PRESSURE AND TEMPERATURE.

purposes. The following figures show the effects of temperature, and the countereffect of pressure adjustments:

Retention of n-butane at 80° F. = 88 per cent total available
Retention of n-butane at 140° F. without adjustment of pressures = 73.8 per cent total available
Retention of n-butane at 140° F. with adjustment of pressures = 82 per cent total available

There is, of course, at all times a slight fall in temperature of the oil as it passes from one stage to the next, due to the latent heat of the evolved gases, but it appears to be counterbalanced to a certain extent by the heat generated in the turbulent flow in the pipes connecting the stages. The observed temperature drop does not exceed 1° F. per stage.

Efficiency of the Haft Kel Plant

The normal gas-oil ratio of Haft Kel crude single-flashed into a flow tank at atmospheric pressure is approximately 468 cu. ft. per barrel. The percentage composition of this gas by volume, together with the quantity of each component, and the amount of each remaining in solution in the crude, are given in Table 1.

TABLE 1.—*Composition of Haft Kel Crude*

Component	Percentage Composition of Gas by Volume	Cubic Feet of Gas per Barrel at Standard Temperature and Pressure		
		In Gas	In Oil	Total
Methane	62.23	291.5	1.58	293.08
Ethane	10.77	50.4	1.98	52.38
Propane	10.55	49.4	7.20	56.60
Iso-butane	3.35	15.7	6.25	21.95
Normal butane	4.82	22.6	12.30	34.90
Pentanes	4.48	21.0	31.60	52.60
Hydrogen sulphide	3.80	17.8	1.03	18.83
Total	100.00	468.4	61.94	530.34

The treatment of this gas by 250-lb. compression gave a gasoline recovery of 2½ gal. (U. S.) per 1000 cu. feet.

Typical operating results of the multistage stabilization plant are given in Table 2. The figures have been obtained by calculation, in order to give comparable values, but they are in good agreement with observed results. In Table 3 these figures are converted into cubic feet per barrel of single-flash crude, with the addition of a column giving the gases obtained in the 10-lb. crude.

From Tables 1 and 3, it is now possible to obtain the efficiency of the process for comparison with the orthodox methods of gasoline recovery.

TABLE 2.—*Typical Operating Results*

	Number of Stage					
	1	2	3	4	5	6
Operating pressure, lb. per sq. in. abs	515	218	102	55	34	25
Temperature, deg. F	105	80	80	80	80	80
Gas evolved, cu. ft. per barrel equivalent single-flash atmospheric crude	210.0	80.8	39.7	20.7	13.4	9.33
Gas analysis, percentage volume:						
Methane	87.62	81.82	68.07	48.52	28.21	14.10
Ethane	6.12	9.12	15.48	23.96	31.37	34.80
Propane	2.64	3.94	7.65	13.33	20.20	26.00
Iso-butane	0.45	0.61	1.36	2.42	3.74	5.00
n-butane	0.59	0.77	1.51	2.77	4.28	5.89
Pentane	0.39	0.46	0.90	1.62	2.58	3.46
H_2S	2.19	3.28	5.03	7.38	9.62	10.75

TABLE 3.—*Gas Content*

Component	Cubic Feet Gas per Barrel Single-flash Crude Removed from Stages						Cubic Feet Gas Remaining in 10-lb. Crude
	1	2	3	4	5	6	
Methane	184.00	66.10	27.00	10.38	3.79	1.32	0.77
Ethane	12.85	7.37	6.15	4.96	4.20	3.25	13.62
Propane	5.55	3.18	3.04	2.76	2.72	2.43	37.00
Iso-butane	0.95	0.49	0.54	0.50	0.50	0.47	18.50
n-butane	1.23	0.62	0.60	0.57	0.57	0.55	30.75
Pentanes	0.81	0.37	0.36	0.33	0.35	0.32	50.00
H_2S	4.60	2.66	2.00	1.53	1.29	1.04	5.75
Totals	209.99	80.79	39.69	21.03	13.42	9.38	156.39

This is given by comparing the increased quantity of each gas retained in 10-lb. crude with the amount in single-flashed gas.

$$\text{Iso-butane} = \frac{18.50 - 6.25}{15.7} = 78 \text{ per cent}$$

$$\text{n-butane} = \frac{30.75 - 12.30}{22.6} = 81.7 \text{ per cent}$$

$$\text{Pentanes} = \frac{50.00 - 31.60}{21} = 87.5 \text{ per cent}$$

These efficiencies compare most favorably with those obtainable by the best design of absorption plant, especially when time efficiency is taken into consideration. Maintenance work on the separators is practically nil and their running time may be taken as 100 per cent, whereas that of an absorption plant generally has between 90 and 95 per cent.

The loss of efficiency in hot weather also applies to the absorption process, but in southwest Iran it is difficult during the summer months to keep the temperature of the seal oil entering the absorbers below 100° F.

HAFT KEL PRODUCTION SYSTEM

So far no mention has been made of the production system at Haft Kel, but it is obvious from the preceding description of the process that multistage stabilization has helped to simplify it considerably.

The output from the field is handled by three units, their capacities being, respectively, 125,000, 65,000 and 40,000 bbl. per day. Fig. 3 shows the largest unit. Each of these units serves groups of from 4 to 10 wells, the output of each well being of the order of 10,000 to 16,000 bbl. per day. Each well is fitted with a separator, one of which is shown in Fig. 4. The remaining five stages of separation constitute the stabilizer unit and are located at elevations of from 1600 to 1900 ft. above sea level, from which they deliver the crude by gravity flow to the first boosting station on the pipe line 60 miles away.

The distance between the wellhead separators and the stabilizer unit is sometimes as much as 3 miles, with a difference in elevation of 500 to 1200 ft., the wells being at the lower level.

The operation of the complete system is illustrated by the simplified oil-circuit diagram in Fig. 5. Beginning at the wellhead separator, there is a liquid-level controller *A* on the inlet line, which acts as the throttling valve or bean on the well. This controller opens if the level in the separator tends to fall, and thereby maintains a constant level in the separator by varying the offtake from the well.

During normal operation, controller *B* on the separator outlet remains wide open, but if the offtake of oil from the separator exceeds the capacity of the well, resulting in a fall off in the separator, controller *B* begins to close and prevents gas from entering the oil line.

The oil from the separator flows through its line to the stabilizer unit, where it joins the lines from the other wells in a common manifold. The total oil enters the second stage of separation, the quantity being regulated by controller valve *C*. If the level of the oil in this separator rises, *C* closes and restricts the flow from the wellhead separators, and vice versa. Similarly the succeeding stages are controlled by the liquid-level regulators on their inlets.

The outlet of the final separator is connected directly to the main pipe line leading to the refinery. The quantity dispatched is adjusted by means of valve *J*, which is situated some miles away down the main oil line at a control point.

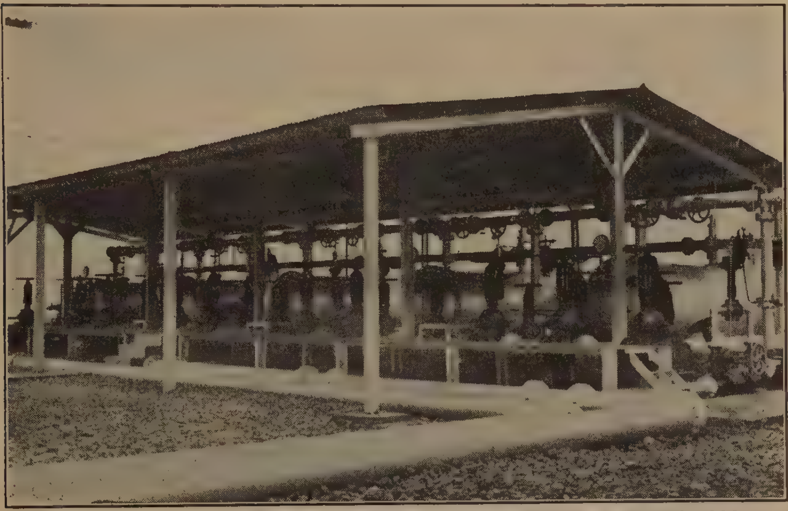

FIG. 3.—MULTISTAGE STABILIZER UNIT, HAFT KEL FIELD. CAPACITY 125,000 BARRELS PER DAY.

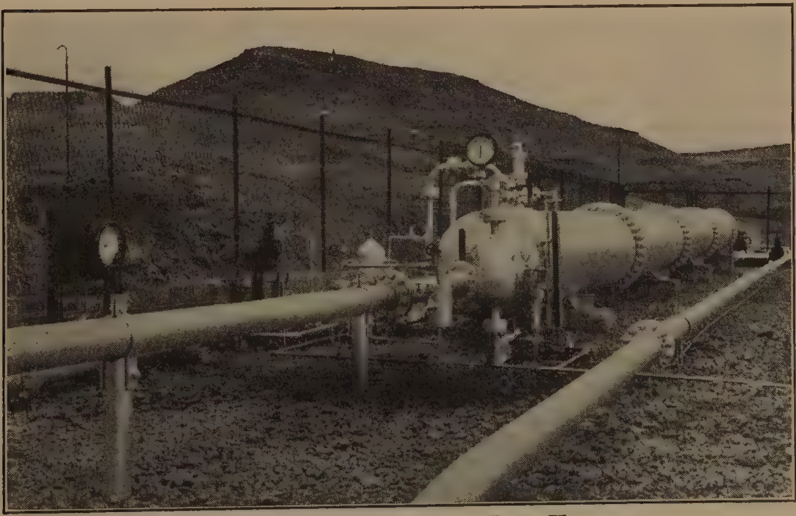

FIG. 4.—WELLHEAD SEPARATOR, HAFT KEL FIELD.

Enough wells are connected to the unit to provide more oil than the maximum possible requirements, but the low-level controller *H* is provided on the discharge side of the final separator to prevent any gas from passing into the main oil line in the event of partial or complete failure of crude supply from the wellhead separators.

ADVANTAGES OF MULTISTAGE STABILIZATION

Multistage stabilization permits an extremely simple and almost entirely automatic production system to be installed. No tanks are included in the production system. If there should be a break on the main pipe line, all the producing wells can be closed in by closing valve *J*. The regulation of pressures with change of temperature also lends itself to automatic control.

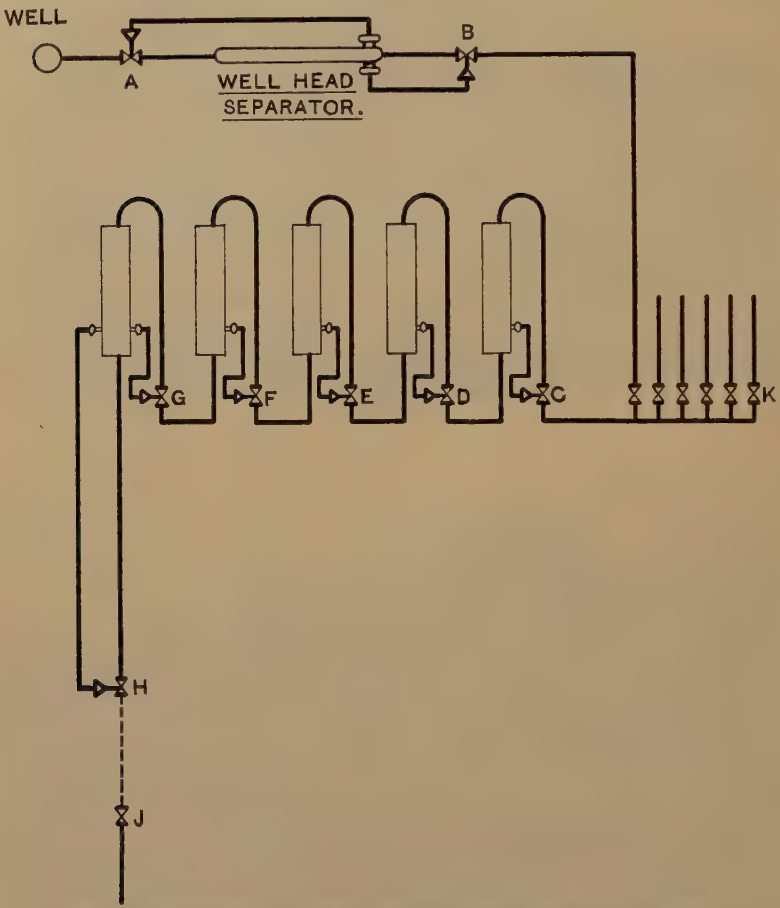

FIG. 5.—SIMPLIFIED DIAGRAM OF STABILIZER UNIT, OIL CIRCUIT. *A* to *H*, liquid-level controllers, *J* and *K*, gate valves.

All the separators are horizontal cylinders; those at the wellheads are 3 ft. in diameter and 60 ft. long, and those comprising the stabilizer unit are 4 ft. 6 in. in diameter and 120 ft. long. The separators have no internal fittings, as it was found after extensive experiments that this type of vessel is the most suitable separator for the multistage process. Probably this is because in each of the stages the actual volume of gas is approximately equal to the volume of oil, and the mixture consists of bubbles of gas carried in a stream of oil, whereas the usual condition in oil-gas separators is that the oil is dispersed as drops in a stream of gas.

The level controllers are fitted near the outlets of the separators, and after flashing across them the oil and gas mixture travels through about 100 ft. of pipe before entering the next stage. The turbulent flow in this pipe ensures that equilibrium is reached between the gas and the oil.

The whole installation has a very low first cost, and the operating and maintenance costs are far below those of an absorption plant handling an equivalent quantity of gas.

Other Applications and Developments

The system of multistage stabilization can be applied with considerable advantage to high-pressure absorption plants, where it reduces the amount of uncondensable gases passing out of the condensers. (Some of the modern plants in the United States of America are using one or two stages of separation between the absorbers and the stills for this purpose.)

The gases evolved from the last four stages of separation at Haft Kel are relatively rich in gasoline (Table 2), and invite treatment for the recovery of their gasoline. The quantities involved, however, are relatively small, and so far it is not possible to make out an economic case for the recovery, involving as it would a departure from that extreme simplicity and economy now obtaining in the Haft Kel field.

A scheme is being investigated, however, to recover this gasoline by compressing these gases to the pressure of the second stage and passing them through an absorber column countercurrent to the crude from the second-stage separator. The gas from the final stage, being the richest, would be put into the bottom of the column and the leaner gases at corresponding points higher up. The crude leaving the absorber would pass back into the separator chain and continue the usual process. The gas leaving the top of the column would approximate the composition of that evolved from the second stage. The power for the compression of the gas would be obtained from the expansion of the high-pressure gas and no cooling would be employed, the gases being injected directly from the compressors into the column, as their total heat would have but little effect on the relatively large bulk of crude. In this way it is aimed to keep the stabilizer units absolutely self-contained and at the same time recover every possible gallon of gasoline, though they will lose a certain amount of their simplicity.

CONCLUSION

The multistage stabilization of crude can be employed to its optimum effect only in fields where the flowing pressures are high and the oil and gas content of the crude are known. It is of greatest value in fields in which otherwise provision for gasoline-absorption plants with their ancillary services would have to be made.

ACKNOWLEDGMENTS

The author wishes to take this opportunity of thanking Lord Cadman and the Board of Directors of the Anglo-Iranian Oil Company Ltd. for permission to publish this paper.

DISCUSSION

(B. C. Craft presiding)

N. D. DRAKE,* New York, N. Y.—This paper shows what can be done to take advantage of natural conditions in producing operations. The use of several stages of separation is an approach to differential liberation of gas; a step further than the two-stage or three-stage separation commonly used in high-pressure gas-return operations. As pointed out in the paper, the successful application of the multistage stabilization is dependent upon the existence of high flowing pressures over a long period of time, and in the Iranian fields there can be little doubt on the question. Operations in fields like those with which the paper deals—those having reservoirs in which the oil is contained in crevices, fissures or extremely porous formations, and is under the influence of very active water drive—probably come close to the petroleum engineer's paradise, where reservoir pressures never decline, wells may be spaced many miles apart and the entire operation simmers down to something approximating control of valves, represented by the wells, tapping a large tank of fluid. It is possible that the multistage stabilization idea as outlined in this paper could be applied to a sand reservoir where pressures are maintained by gas return; the relative advantages between this hookup and the use of one or two stages of high-pressure separation followed by stabilization will very likely depend principally upon the compression cost involved in bringing the produced gas up to injection pressure.

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* Standard Oil Development Co.

Principles of Well Spacing

By Morris Muskat*

(New York Meeting, February 1939)

Although the problem of well spacing is one of the most important involved in the production of oil, it must be considered at the present time as still subject to further development. The published literature on this question is so voluminous that we cannot enter here into a review of it, except to refer to the recent papers by L. L. Foley[1] and E. A. Stephenson,[2] where other references are cited. However, a decisive and conclusive answer to the problem of well spacing in any general form does not seem to have been developed. And while we shall be unable to present the desired solution in the present paper, it is nevertheless felt that the material to be given here not only provides the physical ground work for the ultimate solution, but shows qualitatively the essential factors that enter the well-spacing problem.

Field studies of the well-spacing problem, in which the ultimate recoveries from different fields with different well spacings have been compared, have generally suffered from the lack of knowledge as to the similarity of the inherent characteristics of the producing reservoirs being compared, such as the sand volumes, the sand porosities, the sand permeabilities, the original reservoir pressures, the presence or absence of gas caps, the presence or absence of effective water drives, and the economic limits of production rates at which the various fields were considered to have yielded their ultimate recoveries. Certainly no one who is evaluating originally the economic significance of any oil reservoir would deliberately ignore these phases of the problem. And it is equally certain that no one would reasonably expect the ultimate recoveries from two reservoirs, even with the same well spacing, to be identical regardless of these other factors.

More reliable results might be expected from comparisons of the recoveries obtained from different leases with different well spacings, but producing from the same reservoir sand. Unfortunately, however, even conclusions for such studies may be subject to serious errors. The reason simply is that however much one may insist that an operator is entitled only to the oil immediately underneath his surface acreage he will nevertheless drain the surrounding properties as long as his reservoir

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[1] References are at the end of the paper.

pressures are maintained below that of his neighbors.* In other words, oil will migrate from the surrounding acreage and be brought up through his wells unless the surrounding leases maintain average reservoir pressures that are no higher than his. The intent of the operator with regard to this migration is entirely irrelevant. If he does not know the reservoir pressures in his and the neighboring leases it will go on without his knowledge. If he does know them he may still be forced to induce such migration even against his will if his neighbors are unable to develop and produce their properties as fast as he finds it expedient and desirable to produce his own. Such a situation will always obtain when different parts of a single reservoir are drained at rates that are not all proportional to the oil present under the surface acreage and the wells are produced in such a manner as to create pressure gradients across the reservoir.

Thus let us suppose that one-half of a uniform reservoir that is not subjected to effective edge water or gas-cap drives is drilled twice as densely as the other half. If all the wells are produced at the same rate, it follows that while these rates are maintained the densely drilled acreage will remove twice as much oil as its neighbor. If the sands are otherwise uniform the reservoir pressure in the densely drilled half will fall at a rate that is at least twice as great as that in the other half, provided these two halves are separated by an impermeable membrane. If such a membrane were to really exist, the total recovery from either half, when production had become unprofitable, would directly reflect the effect of the different well spacings used in the two halves. However, in reality no such membrane exists. On the contrary, it is just as easy for oil to flow across the boundary between the two halves in consequence of pressure gradients as it is for the oil to be driven into the producing wells by the pressure gradients directed toward these wells. In other words, as soon as the pressures in the densely drilled half begin to fall below those in the other half oil will begin to migrate from the latter into the former.

In performing such an experiment one would therefore obviously anticipate that the closely drilled half would produce more oil in a limited time than the sparsely drilled half, even if inherently the well density had no effect upon the recovery of the oil that was originally in place in either side of the reservoir. And, indeed, this is the situation that has been frequently observed in field practice and has been universally quoted as supporting the claim that close well spacing will result in higher recovery than will wide spacing. Until the actual recoveries have been corrected for the migration into or out of any acreage that is being used in the study of well spacing, it is clear that the conclusions drawn will not be valid in indicating the value of either close or wide well spacing. As this has not been done in studies made heretofore, and since it is not clear how such corrections can be made accurately, one is forced to question seriously the ultimate significance of tests or studies of this kind.

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* The existence of this factor of migration in the interpretation of field data with respect to the problem of well spacing seems to have been first pointed out by A. C. Rubel[3] and subsequently critically examined by R. D. Wyckoff.[4] In fact, the above discussion is essentially nothing more than a restatement of Wyckoff's conclusions.

In view of these difficulties of obtaining significant data on the problem of well spacing from records of actual field performance,* it appears necessary to resort to deductions made from laboratory studies of the problem. It is the purpose of this paper to develop this point of view. Since the laboratory approach to the problem of well spacing can of itself indicate only the nature of the *physical* solution to the problem, one must obviously supplement this with economic considerations in order to make the results of practical interest. However, it will be well to consider first the nature of the physical ultimate recoveries of oil reservoirs in relation to the well spacing of the drainage system in order to have a proper basis for the discussion of the economic phase of the problem. For this purpose the sands will be considered as uniform throughout the extent of the reservoir. When the producing horizon is broken up into lenses, each of which would certainly contain enough oil to pay for the cost of drilling and operating at least a single well, it is obvious that the spacing must be made sufficiently small to insure a high probability that each individual lens is penetrated by at least one well. It is further to be understood that neither effective water nor gas-cap drives are present as aids in the production. Only the gas originally dissolved in the oil will be considered as a source of energy for draining the sand of its liquid.

PHYSICAL ULTIMATE RECOVERIES OF EXTENDED UNIFORM SANDS

By the detailed calculation of the production history of a column of sand of uniform properties it has been found that the physical ultimate recovery of liquid from the sand is practically constant over its whole extent.[5,6] By the "physical ultimate recovery" we mean that which obtains after an infinite time of production. This in turn implies that the pressure has fallen everywhere to the value maintained at the bottom of the producing wells. The economic phase of the question obviously enters into the problem raised in the attainment of such an ultimate depletion, since it involves the production from the reservoir during its later history at extremely low rates. However, for the present we shall ignore this question and shall suppose this ultimate depletion to be a practicable achievement. There is indeed some variation of the ultimate liquid saturation at the state of complete depletion and, in particular, the recovery of liquid appears to be somewhat higher near the drainage surface than at distant points. However, this increased recovery is concentrated about the outflow surface, and one may reasonably approximate the final result by saying that the ultimate recovery is uniform over the extent of the producing sand.

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* A type of field data pertinent to the problem of well spacing that would automatically take care of differences in sand volume, sand porosity and initial reservoir pressure would consist of the ratio of the initial gas-oil ratio of the field to its average value during its production history. For these ratios would be direct measures of the fractional oil recovery. However, such data, too, would suffer from the complicating effects of free gas zones and water drives in comparisons of different fields, and from interlease migrations in the study of producing tracts in a single field.

While this conclusion has thus far been expressed essentially as a consequence of a particular theoretical calculation and similar direct experimental laboratory tests, it may be shown that they are not to be associated with the special problem for which the calculation was carried through in detail. On the contrary, they have considerable general validity. The proof of this may be deduced directly from the character of the general differential equations governing the flow of gas-liquid mixtures through sands, which have been derived as direct consequences of laboratory experiments. These are the equations governing the space and time distribution of the fluid pressure and liquid saturation in any sand carrying a gas-liquid mixture which, under the assumption of uniform sand permeability, become:

$$\nabla \cdot \{pF_g(\rho)\nabla p\} + \alpha\nabla \cdot \{pF_l(\rho)\nabla p\} = \frac{\alpha f \mu_l}{k_0}\frac{\partial}{\partial t}p\left\{\rho + \frac{c}{s}(1 - \rho)\right\} \qquad [1]$$

$$\nabla \cdot \{F_l(\rho)\nabla p\} = \frac{f\mu_l}{k_0}\frac{\partial \rho}{\partial t} \qquad [2]$$

where p is the fluid pressure, ρ the liquid saturation expressed as the fraction of the local pore volume occupied by liquid, t the time, $\alpha = s\mu_g/c\mu_l$, μ_g, μ_l being the viscosities of the gas and liquid phases, s the solubility of the former in the latter, c the density of the gas at atmospheric pressure, f the porosity of the sand, k_0 its homogeneous fluid permeability, and the differential operator ∇ refers to the space coordinates. It is also assumed for simplicity in constructing equations 1 and 2 that the gas is ideal and obeys Henry's law. The functions $k_0F_l(\rho)$ and $k_0F_g(\rho)$ are the empirically determined values of the permeability of the sand to the liquid and free gas phases expressed as functions of the liquid saturation. These functions represent the hydrodynamic definition of the sand as the carrier of a heterogeneous fluid, just as the permeability k_0 is that for a homogeneous fluid (liquid or gas) flow. The technique required to determine these functions has been described by Wyckoff and Botset (ref. 5, p. 325).

For the linear system these equations reduce to:

$$\left.\begin{aligned} \frac{\partial \rho}{\partial \bar{t}} &= F_l\frac{\partial^2 p}{\partial \bar{x}^2} + \frac{\partial F_l}{\partial \bar{x}}\frac{\partial p}{\partial \bar{x}} \\ \left\{\frac{c}{s} + \left(1 - \frac{c}{s}\right)\rho\right\}\frac{\partial p}{\partial \bar{t}} &= p\left\{\frac{c}{s}\frac{\partial \rho}{\partial \bar{t}} + \frac{F_g}{\alpha}\frac{\partial^2 p}{\partial \bar{x}^2} + \frac{1}{\alpha}\frac{\partial F_g}{\partial \bar{x}}\frac{\partial p}{\partial \bar{x}}\right\} + \left(\frac{F_g}{\alpha} + F_l\right)\left(\frac{\partial p}{\partial \bar{x}}\right)^2 \end{aligned}\right\} \qquad [3]$$

where $\bar{x}$, t are the dimensionless variables defined by: $\bar{x}=x/L$; $\bar{t}=k_0t/f\mu_iL^2$. It is also assumed, of course, that the pressure p is measured relative to some unit pressure, which is to be considered as multiplied into the right side of the expression for $\bar{t}$.

It follows that for a given set of physical constants, included in α, and a certain mode of production—defined, for example, by the character of the variation in pressure or flux at the outflow surface—the saturation distribution at any time and position will be expressed by the universal function $\rho = \rho(\alpha, p_i, \bar{x}, \bar{t})$, where p_i is the initial reservoir pressure. The pressure distribution will be given by a similar function, it being explicitly noted that the absolute length of the system L does not enter into these functions, the parameters of significance being the dimensionless quantities $\bar{x}$ and $\bar{t}$. The total ultimate recovery of a unit cross-section column of sand of porosity f and length L, drained by a single "well" at its center, will therefore be given by:

$$\left.\begin{aligned} P &= 2f\int_0^{L/2}\left[1-\rho\left(\alpha, p_i, \frac{2x}{L}, \infty\right)\right]dx \\ &= fL\int_0^1 [1-\rho(\alpha, p_i, \bar{x}, \infty)]d\bar{x} = F(f, \alpha, p_i)L \end{aligned}\right\} \qquad [4]$$

the ∞ indicating that ρ refers to the state of ultimate depletion.

Thus we see that the total ultimate recovery will be directly proportional to the length of the sand; that is, the average recovery per unit length of sand will be independent of the total length of the system. Furthermore, if there are n identical "wells" draining the column of sand, the total ultimate recovery will still be:

$$\left.\begin{aligned} P_n &= 2nf\int_0^{L/2n}\left[1-\rho\left(\alpha, p_i, \frac{2nx}{L}, \infty\right)\right]dx \\ &= fL\int_0^1 [1-\rho(\alpha, p_i, \bar{x}, \infty)]d\bar{x} \end{aligned}\right\} \qquad [5]$$

which is the recovery obtainable by a single well. With regard to the absolute ultimate recovery of the linear system, there is, therefore, no gain whatever in using more than one well to deplete the column of sand.

For the radial flow system the analytical equivalent of the above result cannot be derived as a rigorous consequence of the differential equations. However, it can be shown to remain valid within the accuracy of practical interest. Thus, returning to the fundamental eqs. 1 and 2, it is readily seen that the significant dimensionless variables corresponding to $\bar{x}$ and $\bar{t}$ in eq. 3 are: $\bar{r} = r/r_e$, and $\bar{t} = k_0t/f\mu_ir_e^2$ where r_e is the radius of the external boundary delimiting the sand system. Furthermore, as there will be in general two boundaries to the system, defined by the absolute dimensions $r = r_w$, $r = r_e$, their ratio $\beta = r_e/r_w$ may be expected to enter as a parameter in the saturation distribution. The final equilibrium saturation after depletion will therefore be a function as: $\rho = \rho(\alpha, p_i, \beta, \bar{r}, \infty)$. Actually, however, the ratio β may be shown to drop out from the function ρ. For from the earlier study[5] of eqs. 1 and 2 it was found that the equilibrium saturation at a closed boundary, which is also an equipressure surface, depends only on the ratio of the initial to final pressure in the system and not on its geometrical properties. Now, the only way in which these geometrical properties enter at the external boundary ($\bar{r} = 1$) is through β. Hence it follows that β must drop out of ρ, leaving for the ultimate depletion saturation $\rho = \rho(\alpha, p_i, \bar{r}, \infty)$. The total ultimate recovery may therefore be written for unit sand thickness as:

$$\left.\begin{aligned} P &= 2\pi f \int_{r_w}^{r_e} \left[1 - \rho\left(\alpha, p_i, \frac{r}{r_e}, \infty\right)\right] r\,dr \\ &= 2\pi f r_e^2 \int_{\frac{1}{\beta}}^{1} [1 - \rho(\alpha, p_i, \bar{r}, \infty)] \bar{r}\,dr \end{aligned}\right\} \qquad [6]$$

To see now the manner in which P varies with the area of the system being drained, we note first from eq. 6 that:

$$-\frac{\partial P}{\partial r_w} = 2\pi f r_w [1 - \rho(\alpha, p_i, 1/\beta, \infty)] \leqq 2\pi f r_w \qquad [7]$$

The maximum variation of P with r_w therefore corresponds to the change in volume of liquid in the sand due to changes in well radius, which, of course, is entirely negligible for all practical purposes. The variation of P with r_e, on the other hand, is given by:

$$\frac{\partial P}{\partial r_e} = \frac{2P}{r_e} + \frac{2\pi f r_w^2}{r_e}[1 - \rho(\alpha, p_i, 1, \infty)] \sim \frac{2P}{r_e} \qquad [8]$$

It immediately follows that $P \alpha r_e^2$, so that again the average ultimate recovery, per unit area, is independent of the total absolute area which the well drains. While it is not possible to fill out a plane area completely by means of strictly circular units, it is clear that for practical purposes the fact that the average recovery in a circular region is independent of the total area of the region also implies that the total ultimate recovery from a large tract with a number of wells in it will be no greater than if that tract were drained by a single well at its center. Here, too, therefore, a close well spacing would not lead to a larger physical ultimate recovery than would wide spacing.

It thus appears that under similar conditions of production the total amount of oil that can be displaced from a sand filled with a liquid that is saturated with gas to a given pressure is entirely independent of the number of wells that are used to withdraw that oil. In other words, the question of well spacing does not really exist from a strictly physical point of view.

ECONOMIC ULTIMATE RECOVERIES AS AFFECTED BY WELL SPACING

While the conclusions just drawn appear to follow from eqs. 1 and 2, it must nevertheless be admitted that in themselves they are essentially only of academic interest. For it has been explicitly assumed in their derivation that the comparisons between the ultimate recoveries under various conditions of well spacing are made only after an infinite time of production.* As previously mentioned, this assumption implies that one has waited until the pressures throughout the sand have become equalized and fallen to those maintained at the bottoms of the wells. A considerable portion of the total recoveries thus obtained would correspond to extremely low rates of withdrawal from the wells, and such as would be not only unprofitable but would moreover definitely incur economic losses in the operations. Indeed, it has been not an uncommon experience to find, especially in tight sands, the pressures between wells to be of considerable magnitude even though it has become necessary to abandon the original wells draining the reservoir because they could no longer yield oil at profitable rates. To have continued to operate these original wells until the pressures between them had fallen to the low values immediately surrounding the wells, so that the depletion throughout the whole sand would have attained its ultimate value predicted by the above theory, would, of course, have been gross economic folly.

It is obviously pertinent, therefore, to inquire whether such theoretical considerations as developed above can also be subjected to the economic limitations of the problem of oil production. For only under such conditions will the implications of the laboratory studies have practical significance. Unfortunately, the mathematical analysis involved in the solutions of the fundamental eqs. 1 and 2 has not reached the stage of development wherein any arbitrary geometrical system can be treated. In fact, only the simplest case, in which the producing reservoir is in the form of a long column of sand, has thus far been analyzed in detail. For this case, however, as we shall see presently, it is possible to apply economic considerations to the problem of well spacing.

The economic restriction that we shall now impose is that the recovery of the oil will not be profitable unless the rate of production per well is equal to or exceeds a preassigned minimum value.* The question to be answered, then, is: How will the total recovery from a tract that is to be obtained with rates of production from the individual wells above this minimum value depend upon the number of wells in the tract? For simplicity, it will be assumed that all the wells in any particular tract are produced in exactly the same manner. Moreover, it will be supposed that this mode of production is that in which all the wells are drilled simultaneously and the bottom-hole pressures are reduced immediately after completing the wells to a tenth of their initial reservoir pressure and thereafter maintained indefinitely until the field is abandoned. Considering this final pressure to be that of the atmosphere, the assumption corresponds to supposing that the initial reservoir pressure in the sand is 10 atmospheres, or approximately 150 lb. These specific assumptions will be used here simply because the only case for which a detailed numerical solution of the fundamental differential eqs. 1 and 2 is available was also developed under these assumptions.

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* While the additional assumptions of strictly constant liquid viscosity and ideal kinetic theory behavior of the gas and liquid reservoir fluids also limit the generality of the conclusions even from the physical point of view, it seems very unlikely that the mere removal of these assumptions would lead to physical ultimate recoveries which vary appreciably with the well spacing.

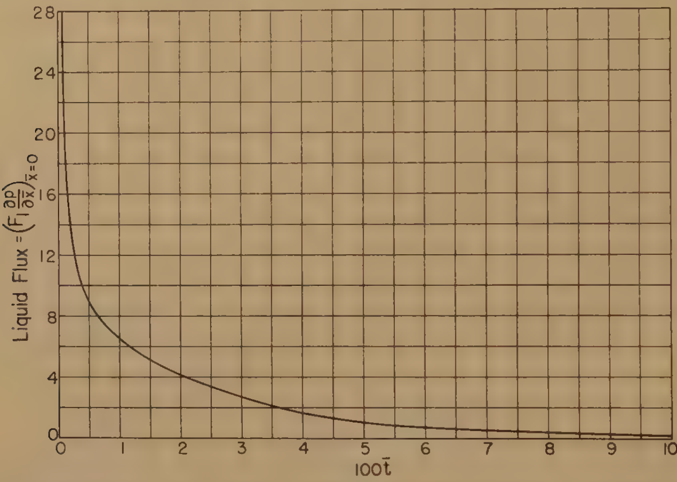

FIG. 1.—DECLINE IN FLUX FROM LINEAR CHANNEL ORIGINALLY SATURATED TO A PRESSURE OF 10 UNITS AND EXPOSED AT ONE END TO A UNIT PRESSURE AND CLOSED AT THE OTHER.

Real flux in cubic centimeters per second per unit area of sand column is $k_0/\mu_l L$ times ordinates. $\bar{t}$ = dimensionless time.

For this particular case it has been found that the velocity of outflow in dimensionless units from such a column of sand as a function of the dimensionless time $\bar{t}$ is given by the curve of Fig. 1. The real flux into the well in cubic centimeters per second per unit area of sand column is $k_0/\mu_l L$ times the ordinates in this figure, where k_0 is the homogeneous fluid permeability of the sand, μ_l the viscosity of the oil, and L the length of sand column on either side of the well, it being supposed that the well bisects the sand and that the latter is closed at its distant terminals.

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* A condition of this kind and the general type of economic interpretation of the well-spacing problem presented here has recently been applied to gas fields by D. T. MacRoberts.[7]

If there are n wells uniformly spaced in the total sand column of length L, the rate of production from each well will be given by:

$$Q_n = \frac{4nk_0}{\mu_l L}\left(F_l \frac{\partial p}{\partial \bar{x}}\right)_0 \qquad [9]$$

where again the quantity in parenthesis is given by the ordinates of Fig. 1. The total rate of recovery from the sand will obviously be nQ_n. The total recovery of oil at any dimensionless time $\bar{t}$ will be given by:

$$P = fL\int_0^{\bar{t}}\left(F_l \frac{\partial p}{\partial \bar{x}}\right)_0 d\bar{t} = fL\int_0^1 [1 - \rho(\alpha, p_i, \bar{x}, \bar{t})]d\bar{x}. \qquad [10]$$

Its variation with $\bar{t}$ is shown in Fig. 2, for the case corresponding to Fig. 1.

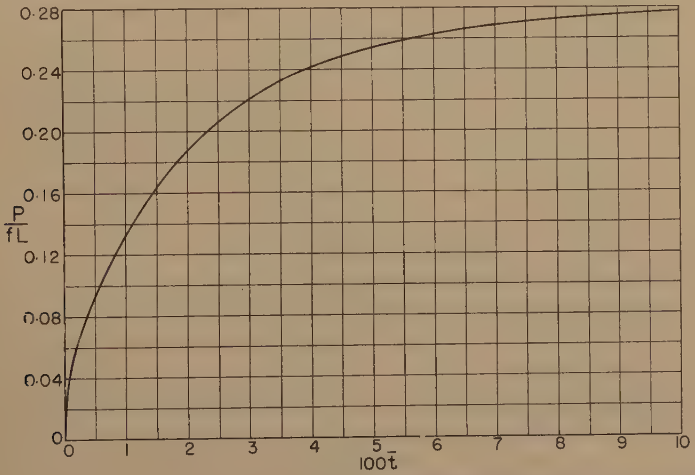

FIG. 2.—VARIATION OF FRACTIONAL LIQUID RECOVERY FROM LINEAR SYSTEM WITH TIME.

P = total liquid recovery per unit area of sand column; f = sand porosity; L = length of sand column; $\bar{t}$ = dimensionless time.

We are now ready to impose the economic limitations mentioned above; namely, that the ultimate recovery is to be considered as having been obtained when the production rate Q_n has fallen to a limiting minimal value, which we may denote by Q_{n0}. This means, by eq. 9, that the minimal value of the ordinates of Fig. 1 of economic significance will be that corresponding to:

$$\left(F_l \frac{\partial p}{\partial \bar{x}}\right)_0 = \frac{\mu_l L Q_{n0}}{4k_0 n} \equiv \frac{\bar{Q}_0}{n} \qquad [11]$$

where $\bar{Q}_0$ is the minimum production rate expressed in dimensionless terms, and it is supposed that the pressures p have been taken throughout as being measured relative to a unit pressure. Thus choosing Q_{n0}, and therefore $\bar{Q}_0$, one can easily find from Fig. 1 the dimensionless time $\bar{t}$ at which the recovery is to be considered as complete from an economic point of view for any number of wells n. From Fig. 2 can be obtained immediately the total fractional recovery up to that time, or the total economic ultimate recovery.* Moreover, this procedure also gives the absolute value of the time by which this economic ultimate recovery will be obtained, since:

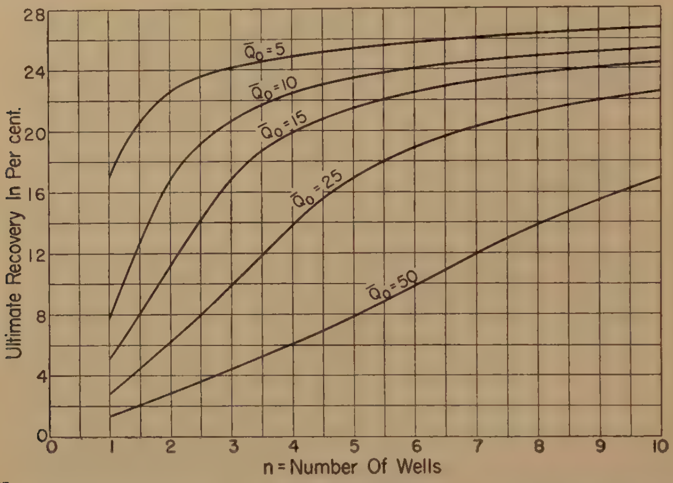

FIG. 3.—VARIATION OF ECONOMIC ULTIMATE RECOVERY OF LIQUID FROM LINEAR SYSTEM WITH NUMBER OF WELLS n.

$\bar{Q}_0 = \mu_l L Q_{n0}/4k_0$; k_0 = sand permeability; μ_l = liquid viscosity; L = total length of system; Q_{n0} = minimal production rate (per unit sand cross section) per well at which the well can be produced profitably.

$$t = \frac{f\mu_l L^2 \bar{t}}{4n^2 k_0}. \qquad [12]$$

The ultimate recoveries obtained as just described are plotted as a function of the number of wells draining the linear system in Fig. 3.

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* These two steps could be combined analytically into the single equation: $P = -fL\int_{\bar{Q}_0/n}^{\infty} v_0 \frac{d\bar{t}}{dv_0} dv_0$ where $\left(F_1 \frac{\partial p}{\partial \bar{x}}\right)_0$ is denoted by v_0. However, this would require calculating the slopes $\frac{d\bar{t}}{dv_0}$ from a curve (Fig. 1) which is not known very accurately, whereas the integrated form: $P = fL\left[\frac{Q_0}{n}\bar{t} + \int_{Q_0/n}^{\infty} \bar{t}\, dv_0\right]$ would still involve using Fig. 1, together with that for $\int \bar{t}\, dv_0$.

The practical significance of the dimensionless minimal production rate $\bar{Q}_0$ is given by the observation that a minimal rate of 0.1 bbl. per day per square foot of sand of an oil of 5 centipoise viscosity produced from a sand with a permeability of one darcy and 1000 ft. long corresponds to a value of $\bar{Q}_0 = 7.55$.

The fact that the curves with smaller $\bar{Q}_0$ lie above those with larger values of $\bar{Q}_0$ simply means that, as would have been anticipated, the ultimate economic recovery for the linear system under consideration will increase as the minimal production rate for abandonment decreases. Likewise, for a given minimal production rate the ultimate fractional recovery will decrease as the permeability decreases, since by eq. 11 $\bar{Q}_0$ is inversely proportional to the permeability. And finally, the recovery will decrease with increasing viscosity of the oil, for a given number of wells and for a fixed minimum production rate at which the operations would become unprofitable. On the other hand, it is to be noted that the ultimate recoveries will not vary in a simple manner with the value of $\bar{Q}_0$, the actual dependence on $\bar{Q}_0$ being determined by the number of wells. Thus, whereas for low well densities the recovery is roughly inversely proportional to $\bar{Q}_0$, the variation is much less for the higher well densities. Hence one cannot simply conclude that by doubling the minimal production rate the economic ultimate recovery will be necessarily halved, or that by doubling the sand permeability the ultimate recovery will be doubled.

Of more importance than these features of Fig. 3 is the variation of the ultimate recovery from the column of sand with the number of wells n. Here we find a marked dependence upon the absolute value of $\bar{Q}_0$. For small values of $\bar{Q}_0$ the recovery increases rapidly to approximate saturation as n increases, whereas for large values of $\bar{Q}_0$ the increase in recovery as the number of wells increases is much more gradual. While the details of these curves must be accepted simply as consequences of the analysis and the calculations of the decline history of the particular system as expressed in Figs. 1 and 2, their general features can be given a reasonable physical interpretation. Thus the sharp rise and marked flattening of the curves for small values of $\bar{Q}_0$ implies that for a highly permeable sand column little additional recovery would be gained by increasing the number of wells if the minimal production rate is kept fixed. Or, if we consider sand columns of the same permeability, it means that when the minimal production rate has been set at a low value one approaches, even with a small number of wells, so closely to the physical ultimate recovery that further drilling will add but little. On the other hand, the flatness of the curves for large values of $\bar{Q}_0$ when n is small indicates that if the sand column is very tight one must make the spacing rather close to obtain appreciable recoveries before the operations become unprofitable. Likewise, if the limiting production rate is for some reason unusually high the limiting dimensionless time as determined by Fig. 1 will be in the part of the curve that is very insensitive to changes in the fluid velocity. Decreasing the effective value of the latter by moderately decreasing the well spacing will therefore add little to the total ultimate recovery.

The fractional recoveries produced by each well are plotted in Fig. 4. It will again be noted that for small $\bar{Q}_0$ the recovery per well from the linear system decreases with decreased well spacing, whereas for large $\bar{Q}_0$ the additional wells will produce just as much as the first few. On the other hand, it should be understood that if the number of wells is appreciably increased beyond 10, all the curves of Figs. 3 and 4 will tend to merge, so that even those for large $\bar{Q}_0$ will show saturation in Fig. 3 and definite decline in Fig. 4.

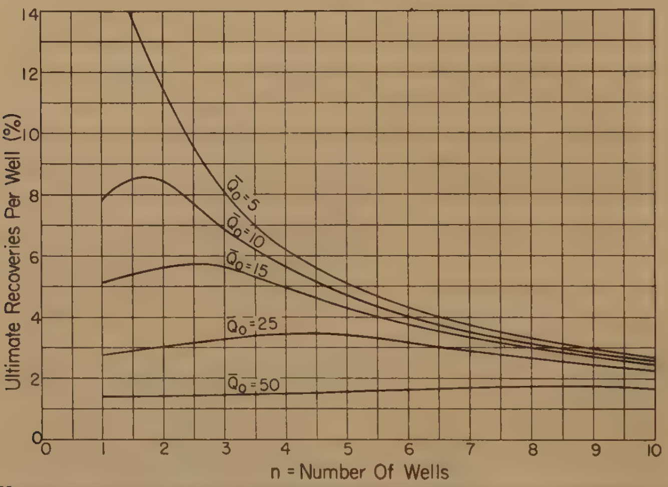

FIG. 4.—VARIATION OF ULTIMATE RECOVERIES PER WELL WITH NUMBER OF WELLS n. Expressed as percentage of total volume of liquid in complete reservoir.

The variation of the time required to produce the economic ultimate recoveries with the number of wells is shown in Fig. 5. Here the general trend is that of decreasing time of recovery with increasing number of wells, the anomalous behavior at very low densities reflecting the approximations or errors in the numerical calculations rather than significant physical features. As to the numerical meaning of the ordinates of Fig. 5, it may be noted that the value of the ordinate of 0.1 corresponds to 2688 days for a sand that is 1000 ft. long, has a porosity of 20 per cent, a permeability of 1 darcy, and produces an oil of 5 centipoise viscosity. Moreover, the values for n for such a sand correspond to an average well separation of 1000 ft. for $n = 1$, 500 ft. for $n = 2 \cdots$ up to 100 ft. for $n = 10$.

LIMITATIONS OF THE ANALYSIS

These results, of course, are subject to a number of limitations due to the assumptions made in the theoretical analysis. Perhaps the most serious of these are the assumptions that the flow system is linear and that the operation of the wells corresponds to wide open production. As far as the nature of the geometry of the flow system is concerned, it is doubtful whether the general character of the results given here will differ for radial systems from that for the linear sand columns. While the decline curves will not be identical with that shown in Fig. 1, their main

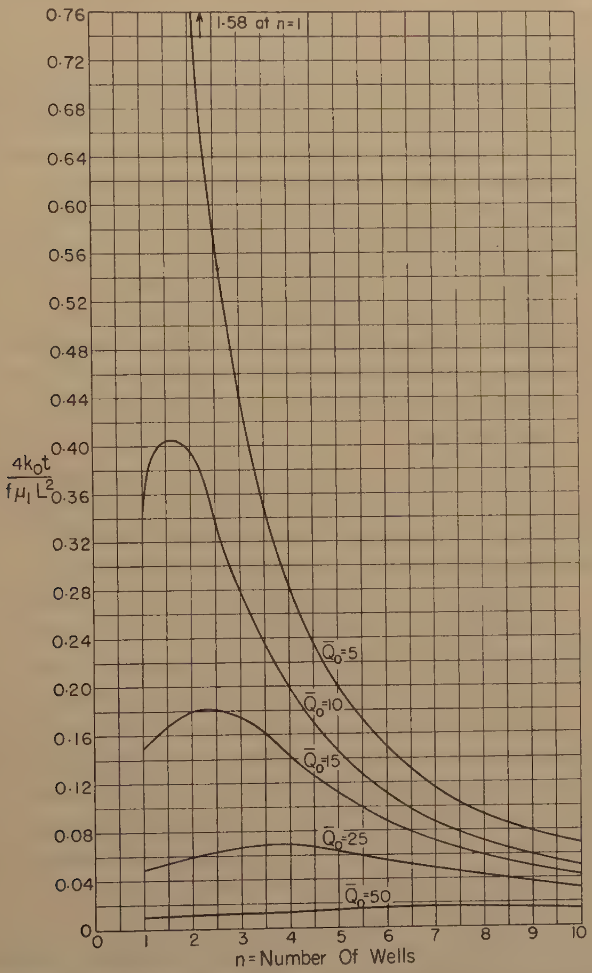

FIG. 5.—VARIATION OF TIME REQUIRED FOR ATTAINING ECONOMIC ULTIMATE RECOVERY FROM LINEAR RESERVOIR WITH NUMBER OF WELLS n USED TO DRAIN RESERVOIR.

trend will undoubtedly be the same. On the other hand, we do not yet know how to translate a specific rate of production for the radial system such as, for example, 1 bbl. per day per foot of sand, into an equivalent rate for the linear system; i.e., in terms of barrels per day per square foot of sand. It is impossible, therefore, to apply the present theory numerically to radial systems and hence to practical well-spacing programs.

With regard to the effect of the manner of production upon the well-spacing problem, it is again impossible to state definite conclusions. From the point of view of the actual analysis, the method of production will play an important role. Thus if we should suppose that instead of flowing the wells wide open their production is prorated to a fixed rate throughout their whole life, the production-decline curve obviously will lose its meaning. Rather, one will have to construct pressure-decline curves, and determine the total recoveries at the time the bottom-hole pressures have fallen to their minimal practical values with various daily prorated production rates. Such generalizations must also be left to future analytical and experimental work. However, it appears unlikely that the well-spacing problem will be seriously affected by the details of the mode of production.

Finally, it should be emphasized that the numerical results given here, or those obtained by any equivalent theory, will depend exclusively upon the details of the decline curve such as shown in Fig. 1. In fact, any type of quantitative prediction with regard to the well-spacing problem can be obtained by suitably varying the character of the dimensionless decline curve with which one begins. Thus, if one begins with the decline curve corresponding to a linear compressible homogeneous liquid system, one obtains total economic ultimate recovery curves similar in type to Fig. 4, but sufficiently different in detail to lead to per well recoveries that uniformly decrease with increasing well density rather than to maxima in the curves such as indicated in Fig. 4. And the curves for the time of recovery corresponding to Fig. 5 also show appreciable changes. As previously mentioned, the maxima in the curves of Figs. 4 and 5 probably have no physical significance but arise from the approximations inherent in the numerical solutions of eqs. 3, which underlie all the quantitative results of this paper. Moreover, in any development of an actual well-spacing program it would be necessary to take into account further economic factors such as interest on investment and price of oil, which have not been explicitly included in the above theory.

No claim is made, therefore, that the well-spacing problem has been given a numerical or quantitative solution here. The purpose of this paper has not been to derive such an ultimate solution, but rather to present the physical bases upon which the well-spacing problem for any particular system should be treated and to show by an idealized example how the analytical program could be carried through. On the other hand, it may not be an entirely fortuitous circumstance that the numerical results that have been derived for the linear system parallel so closely the general opinions heretofore declared with regard to the well-spacing problem, even though they have been founded upon questionable interpretations of field experience.

SUMMARY

As a result of the study reported here, it may be concluded that from a strictly physical point of view there is no basis for believing that the absolute ultimate recovery of oil that can be produced from a uniform and nonlenticular sand through the agency of the dissolved gases will materially depend upon the number of wells used to drain the reservoir. There is, however, a definite variation of the *economic* ultimate recoveries that can be derived from a given reservoir with the number of wells, if we consider the economic ultimate recovery to refer to that which can be obtained with the individual well-production rates exceeding a preassigned minimum. For a linear system, which has been treated in detail, it has been found that this economic ultimate recovery will increase as the number of wells that are used increases. When the minimum limiting production rate is small or the sand columns are highly permeable, the economic ultimate recovery rapidly rises as the number of wells is first increased, but quickly attains values that are thereafter no longer appreciably increased by further drilling. For tight sand columns, or if the lowest production rate at which the operation of a well would still be profitable is high, one must make the well spacing fairly small in order to approach ultimate recoveries that would be obtainable in highly permeable sands or with low minimal production rates.

Although but little practical significance can be attributed to the numerical results derived, because of the various assumptions underlying the details of the analysis, their broad features show a close correlation with general opinion regarding the well-spacing problem that has been previously expressed in the literature.

ACKNOWLEDGMENT

The author is indebted to Dr. Paul D. Foote, Executive Vice President, Gulf Research & Development Co., for permission to publish this paper.

REFERENCES

1. L. L. Foley: *Oil Weekly* (Oct. 11, 1937) 100.
2. E. A. Stephenson: *Oil Weekly* (June 27, 1938) 25.
3. A. C. Rubel: Amer. Petr. Inst. *Prod. Bull.* 209 (1932) 19.
4. R. D. Wyckoff: Amer. Petr. Inst. *Prod. Bull.* 216 (1935) 109.

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5. M. Muskat and M. W. Meres: *Physics* (1936) **7,** 346.
6. M. Muskat, R. D. Wyckoff, H. G. Botset and M. W. Meres: *Trans.* A.I.M.E. (1937) **123,** 69.
7. D. T. Mac Roberts: *Trans.* A.I.M.E. (1938) **127,** 146.

DISCUSSION

(*B. C. Craft presiding*)

R. J. Schilthuis,* Houston, Texas.—Dr. Muskat's paper presents an excellent analysis and statement of the physical principles governing the behavior and the localized and regional movements of gas and oil within reservoirs. It throws the proper light on the significance of this behavior relative to the problem of well spacing and its influence on ultimate recovery.

Well-spacing practices in this country, particularly in Texas, have been motivated entirely by competitive economic conditions with no proper consideration to either physical efficiency or the over-all economic efficiency of the operations. The result of this situation has been a great deal of over-all economic waste, as well as often to lead to physical inefficiency.

The paper is very timely in laying the groundwork for, and indicating the true answer to, the physical aspects of the well-spacing problem and its influence on recovery. The fact that well-spacing practice in the past has given way almost entirely to purely competitive economic conditions, ignoring sound physical as well as economic considerations is rapidly bringing on a critical situation in many areas today relative to per well allowables, payouts, etc. For this reason, Dr. Muskat's paper and conclusions are deserving of very careful attention and consideration by the oil operators, as well as the various state regulatory bodies.

In connection with the purely physical considerations in Dr. Muskat's paper, there is one question I would like to raise; the possibility of the importance of the effects of gravitational forces in bringing about zonal segregation between the oil and evolved gases during the course of production and the possible relation of this effect to the well-spacing problem.

T. A. Pollard, San Francisco, Calif.—Dr. Muskat has shown a certain "ultimate recovery" for a well or wells, predicated on a number of conditions, one of which was the reduction of the bottom-hole well pressure in the beginning to a fraction of the original reservoir pressure, and maintenance of the well pressure at the same value throughout the life of the well. What would be the effect on the "ultimate recovery" if the well pressure were first reduced to, say, 90 per cent of the original reservoir pressure, then 80 per cent, and so on to depletion, thus simulating a restricted or prorated condition?

N. D. Drake,† New York, N. Y.—This paper must be regarded as one more of the series of extremely valuable contributions to our knowledge of reservoir fluid behavior that have been made by Dr. Muskat and his co-workers. It would seem that it is now possible to show beyond a reasonable doubt the factors involved in reservoir drainage in an ideal reservoir, and the principal remaining obstacle to widespread practical application of the fundamental principles already disclosed would seem to be the question of physical changes in the reservoir system during productive life. Among these changes already appreciated are the changes in permeability to oil caused by variation in saturation, and the separation of oil and gas within the sand. The latter is perhaps least susceptible at the present time to analysis, or perhaps it may be better said that it is most difficult to estimate the effect of this phenomenon in actual operations.

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* Humble Oil and Refining Co.

† Standard Oil Development Co.

The discussions that have been carried on in recent years regarding the possible drainage of energy through stratification or slippage of gas without the drainage of oil are well known, and a case often cited as an illustration is the Mansion area at Oklahoma City. If in certain types of reservoirs there is going to be a substantial separation of oil and gas within the oil sand, it is to be inferred that spacing considerably closer than that indicated by mathematical analysis would be required to efficiently drain the oil, but the burden of proof on this point would seem to lie on those favoring close spacing for this or some other reason. It can be shown that any degree of stratification of oil and gas within the sand with subsequent flow of gas unaccompanied by oil to the well bore is a function of the gravity gradient, the horizontal or flowing gradient and the physical characteristics of the reservoir. Looking at these factors, it seems that for any given set of conditions the relation between these two pressure gradients at, say, 1000 and 2000 ft. from the well bore would be very slight, hence the inference would be that the wider spacing would cause very little, if any, loss in oil recovery because of stratification. Putting it another way, it could be said that given a certain reservoir condition—that is, a certain degree of dip and vertical-horizontal permeability relationship—any well spacing, except one ridiculously close, will allow a certain degree of separation of oil and gas in the reservoir at some distance from the well bore, but as between, say, 20 and 40 or 80 acres per well, the difference is slight.

One phase of well-spacing studies frequently misunderstood is the effect of the time factor. It has been shown by Dr. Muskat and others that ultimate recovery in the ideal reservoir is to a large extent independent of the well spacing, time being the major consideration in the depletion of the sand. Under ideal conditions, the time required for recovery of a given amount of oil varies approximately as the square of the well spacing; that is, with twice the distance between wells the time required for drainage will be four times as great, and this fact has often been used to argue against 40-acre as compared to, say, 20-acre, spacing. The main point overlooked in such an argument when considering practical time limits is the fact that the time required to drain the oil with the closer spacing must be ascertained before any assumptions as to the time element on the wider spacing are justified. For example, a 20-acre spacing, purely from the standpoint of hydrodynamics, may be able to drain a given sand in five years even though under proration or some other restriction 20 or 30 years may be assigned for depletion. In such an area, doubling the spacing distance would result in the drilling of only one-fourth the number of wells, yet under the fourfold rule, the wider spacing would be entirely adequate to yield the recoverable oil within the 20 or 30-year period.

R. A. Cattell,* Washington, D. C.—Perhaps what I am going to say should be prefaced with the suggestion that we may be placing too much emphasis on maximum ultimate recovery in our consideration of well spacing. The objective, from a national standpoint, should be to obtain the greatest benefit from our petroleum reserves rather than the greatest number of barrels of oil. The nation and its people need a dependable supply of oil at reasonable prices over a long period—not a flood of oil at low prices in one period and a shortage, with resultant high prices, in another. The operator's financial welfare depends upon the return on his investment rather than upon the quantity of oil he produces.

I do not wish to say that it is necessary to reduce ultimate recovery to accomplish the objective of a relatively uniform and dependable supply over a long period.

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* U. S. Bureau of Mines.

However, if it were necessary to sacrifice something in ultimate recovery by current methods of operation to accomplish that objective, perhaps as a nation we could afford to make the sacrifice. A considerable part of the oil left underground when fields are depleted by usual methods may be a reserve that can be drawn upon when conditions demand or justify expenditures for mining and other methods of recovery that now are too costly for general adoption.

Dr. Muskat has mentioned the difficulty of obtaining conclusive evidence from analysis of field data. H. B. Hill and R. K. Guthrie, of the Bureau of Mines office at Dallas, have plotted recoveries in barrels per acre-foot of sand as ordinates, against spacing in acres per well as abscissas, for groups of fields that have been operated substantially to economic depletion under open-flow methods and are similar in sand characteristics and other attributes. When average values for the individual fields in such a group of similar fields are plotted, the curve trends downward with decreasing slope in the direction of wider spacing. That is, such curves are concave upward and tend to flatten as the well density is decreased. The hypothetical recoveries in barrels per acre-foot with an infinite number of wells, indicated by extrapolating such curves to the ordinate, seem reasonable.

If, using the same ordinates, recoveries per acre-foot of sand from tracts with different spacings in the same field are plotted against acres per well, the curves are steeper than those based on average data for entire fields, showing more pronounced increase in ultimate recovery with the closer spacing. This clearly reflects regional drainage.

Dr. Muskat indicated that he would expect higher ultimate recoveries in fields with closer spacing if the fields considered were comparable as to sand conditions and other features, because operation of a well ceases when the economic limit of rate of production is reached, instead of continuing to infinite time. However, there is one element that should not be overlooked in plotting field data in the manner I mentioned. The tendency of the operator is to select closer spacing in the areas where sand conditions are better, so the upward trend of the curve in the direction of closer spacing may be due to two influences: First, a higher ultimate recovery as a result of closer spacing, and second, a higher ultimate recovery in the more closely spaced areas due to better sand conditions in those areas. However, critical examination of some of the data giving curves of the type mentioned fails to disclose any superiority of sand conditions in the more closely spaced fields.

If curves of this type can be accepted as showing a relation of spacing to recovery (we are not ready to accept them without further study) it is possible with corresponding decline curves to make an economic analysis to determine the spacing that would give the greatest profit under the older methods of production. Also, if we can determine what departures from such curves result from controlled and improved methods of operation, the economic analysis can be extended to apply to fields operated in accordance with the later practice.

Such an economic analysis must be based on an assumed price for oil. If an analysis based on the current price for oil should disclose that the greatest profit comes with closer spacing than is now generally practiced, and operators were to change their spacing accordingly, one might then expect a decrease in price of oil, which would invalidate the economic analysis on which the closer spacing was based.

The Bureau is endeavoring to obtain data concerning fields operated under controlled-production methods for comparison with data from the older fields. The difficulty is that the history of fields operated by the new methods is short, and such fields have not been produced to exhaustion. Comparisons must be based upon estimated rather than proved ultimate recoveries in the newer fields, and a long "foresight" must be projected from a short "backsight." However, our engineers have osme data that indicate that fields operated with pressure maintenance are higher recoveries than fields with the same spacing operated under the older methods. With data of that kind it may be practicable to make economic analyses in which the cost of pressure maintenance can be compared with the cost of additional wells to gain the same recovery.

These remarks are more or less premature, and I have no desire that any definite conclusions be drawn from them. My main purpose in this discussion is to give a suggestion of some of the studies the Bureau's engineers are making, and some of the factors that are puzzling us, primarily with the hope that as a result we may obtain further data and ideas that will bear upon the work. If any of you can refer H. B. Hill, H. C. Miller, or other members of our staff who are engaged in Bureau work that bears upon well spacing, to information that discloses differences in recovery between fields of similar types produced by open-flow methods and by controlled methods, we shall be appreciative.

H. H. POWER,* Austin, Texas.—It is evident that Dr. Muskat's paper applies principally to a pool where the principal source of energy to drive the oil toward the well is the gas dissolved in and produced with the fluid. As I understand it, his analysis is rather definite, in so far as it applies to radial two-dimensional flow under such conditions of reservoir control. To what extent have reservoirs under varying degrees of hydraulic control been analyzed, and what fundamental issues are involved in so far as the spacing pattern is concerned, and, more particularly, what would the author consider to be the radius of drainage of such wells for proper and efficient drainage of the oil content?

M. MUSKAT (author's reply).—Mr. Schilthuis' reaction that this paper provides a sound attack upon the well-spacing problem is indeed gratifying, in view of the extensive fundamental researches by himself and his co-workers on the principles of oil production. His question regarding the effects of gravitational forces in bringing about zonal segregation between the oil and evolved gases during the course of production is well taken. Indeed, such effects must be present. Although we cannot yet estimate quantitatively their magnitude, we may be certain that in general gas segregation will be more pronounced under wide well-spacing conditions than for close well spacings. As such segregation, moreover, will be conducive to gas by-passing and hence inefficient oil recovery, the close well-spacing program may for this reason possess an advantage over wide-spacing plans. In practice, however, this difference may be entirely insignificant, as its magnitude may be so small as to be entirely counterbalanced by the economic factors related to the cost of drilling and the time of payout, etc. Moreover, the physical effect in itself will be largely eliminated in producing formations separated by shale breaks or where the vertical permeability as a whole is appreciably less than the horizontal permeability.

With regard to Mr. Pollard's question concerning the effect on the ultimate recovery of stepwise reductions of the bottom-hole flowing pressures, I can only repeat from the text of the paper the feeling that it appears unlikely that the well-spacing problem will be seriously affected by the details of the mode of production. We are attempting to generalize the analysis so as to obtain more quantitative predictions for such effects, but we are not yet able to draw any general conclusions.

Mr. Drake's discussion of the effect of gas segregation is in agreement with our point of view. Quantitatively, however, we would hesitate to predict with certainty the exact range of practical conditions where this phenomenon would or would not be serious. Mr. Drake's comments regarding the time element in well-spacing considerations are also well taken. At the present time the extended periods of payouts resulting from proration cannot be ignored. Qualitatively, proration control would certainly tend to decrease the gap between the life periods of fields producing under wide and close spacing. On the other hand, it may still be true, under certain conditions, that the restrictions imposed by proration may automatically disappear in the early history of a field, owing to the failure of the wells to make their allowables even under open-flow conditions. In such cases, which, of course, exclude effective water-drive fields like East Texas, the depletion time for the closely spaced wells may still remain appreciably smaller than for widely spaced wells. These are admittedly only possibilities and it is not proposed that they represent any general situation or rule.

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* Professor of Petroleum Engineering, University of Texas.

Mr. Cattrell's brief summary of the recent work of the Bureau of Mines on well spacing is interesting. The distinct difference between the curves for wells obtained from different fields and those from tracts in the same field is certainly a gratifying confirmation of our interpretation of the significance of field data. We also agree with the desirability of ultimately applying the physical data of recovery vs. well spacing to practical economic situations to see what the curves of profit vs. well spacing might look like. We are planning to carry out this type of calculation on the basis of our theoretical analysis of the well-spacing problem, and it will be interesting to see how they will compare with those obtained by the Bureau of Mines in using the results they are gathering from field experience. Of course, we agree that the oil recovery observed with any particular field developed over its actual production history does include the effect of the well spacing characterizing the development. Our only fear with regard to the use of such field data lies simply in the uncertainty as to the degree to which the recovery reflects the well spacing and that to which it reflects the sand and fluid characteristics, the structural features of the field, and such other items as edge-water drives or gas-cap drives. If the work of the Bureau of Mines satisfactorily eliminates these other factors, without question the field data should be entirely trustworthy and significant.

Answering Professor Power, I should like to stress that our treatment of the well-spacing problem as given in this paper is explicitly restricted to linear systems. For this reason we feel that it can correctly give only the principles and trends involved in the problem rather than any quantitative magnitudes. We are attempting to extend the analysis to radial flow systems and if that should be successful we shall have results of more immediate practical applicability. As to the matter of reservoir control, it is true that we have considered only the phase of the production involving the evolution and flow of the gas originally dissolved in the oil. The inclusion of the effects of edge-water encroachment appears at present to be extremely difficult to carry out quantitatively. Qualitatively, however, our studies indicate that whatever changes water drives may make upon the general picture, it will be such that the differences between the economic recoveries under close and wide spacing will be decreased by the effects of water drives as compared to those obtained when water drives are entirely absent.

Radial Filtration of Drilling Muds

By Milton Williams,* Junior Member A.I.M.E.

(Galveston Meeting, October 1939)

It is generally recognized that fluid is lost from rotary drilling muds to permeable strata during normal drilling operations;[1,2,3] but that this fluid is the filtrate from the mud, rather than the mud itself, has been shown by various workers.[1,4,5]

The presence of this filtrate in oil-bearing or gas-bearing strata is undesirable and harmful. The decreased permeability of the stratum to oil effected by the presence of water has been pointed out by several investigators,[6,7] and since, in the production of the reservoir fluid, the greatest pressure drop occurs immediately adjacent to the borehole, it follows that infiltered water is particularly objectionable in this region. Again, this filtrate tends to make electrical logs less reliable, since oil in the proximity of the borehole is probably flushed out to an appreciable extent by the water.[8] Observation of side wall cores may be misleading for the same reason. Drill-stem tests in low-pressure areas may be of doubtful value where no oil is recovered, unless sufficient time is allowed for production of water lost from the mud. The infiltered water may hinder drilling operations by softening shales and causing sloughing; the "tight hole" occasioned by excessive deposition of filter cake in the hole is a common occurrence. The filter cake remaining on the face of the producing formation may itself sometimes be detrimental to production.[9]

In view of these implications of the importance of filtration of mud, an investigation was undertaken to determine the factors involved in the infiltration process, and to correlate these in such a manner that the values obtained in routine filter tests employing a conventional filter of the "wall-building tester" type,[10] together with data on size of hole, drill pipe, and rate of mud circulation, could be used to estimate water loss and distance of penetration of the filtrate into strata.

Quantitative relations of filter-cake permeability, filtrate viscosity, and rate of filtration have been developed for filtration in the simple laboratory filter.[4a,11,12,13] It is obvious, however, that the conditions

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* Humble Oil and Refining Co., Houston, Texas.

[1] References are at the end of the paper.

under which the mud is tested in this procedure are not similar to those prevailing in drilling wells, where the mud is circulated past the filter cake deposited on the face of the strata. Consequently, in this work filtration under drilling conditions was simulated as closely as was feasible with the laboratory equipment available, and the results were correlated with data from the simple laboratory filters.

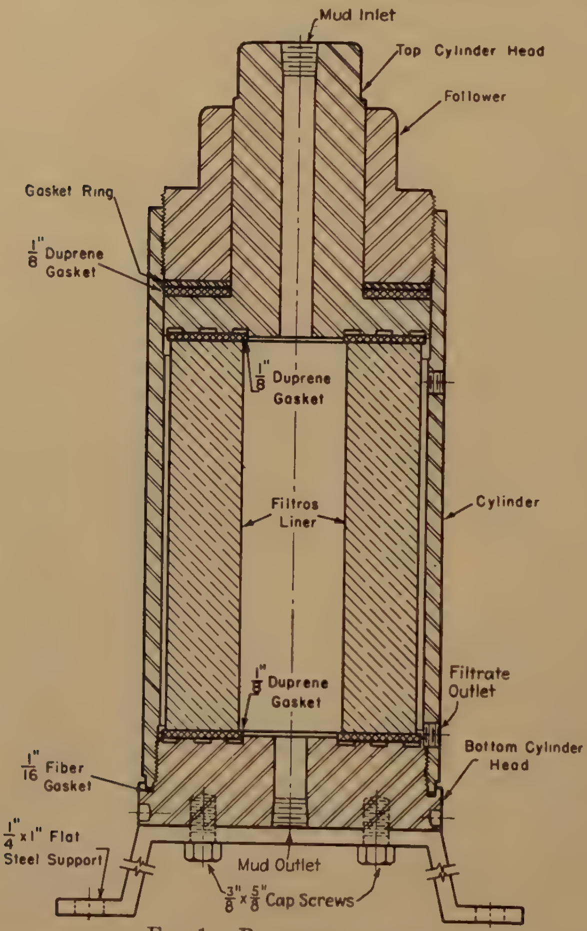

FIG. 1.—PRESSURE FILTER.

FILTRATION WITH AXIAL MUD FLOW

Apparatus, Procedure and Results

Apparatus.—The construction of the filter and the arrangement of apparatus used in all tests are shown in Figs. 1 and 2, respectively. The filter consisted of a porous "Filtros" cylinder (of a siliceous synthetic material) contained in a steel holder: the inside diameter of the cylinder was 1.5 in. (3.8 cm.); the length was 5.9 in. (15.0 cm.). The permeability was determined to be 1.3 darcys.

A 2½ by 4-in. pump, powered with an electric motor, was used to circulate the mud; pressure on the filter was adjusted by use of a by-pass, with gate valves in the by-pass and below the filter. Pressure was read from a gauge teed into the line just above the filter; the rate of mud flow was determined by measurement of the volume of mud discharged from the filter in unit time.

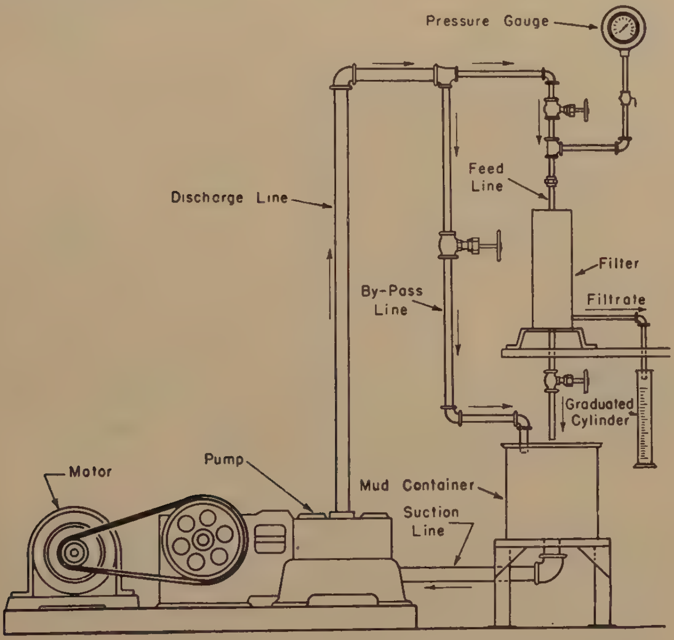

FIG. 2.—FILTRATION APPARATUS.

The evaluation of "filtration constants"[11] for each mud sample run was carried out in simple brass filters, using filter paper as a filtering medium.

Procedure.—Runs were made on: (1) a typical Gulf Coast mud, (2) a sample of that mud treated with 0.1 per cent by weight of sodium tannate from quebracho extract, (3) a sample treated with 1.0 per cent by weight of salt, (4) a mud containing 6.5 per cent Wyoming bentonite in tap water, and (5) a Gulf Coast mud weighted with a commercial weighting material to 15.0 lb. per gal. The filtration constants for these muds are shown in Table 1.

The pressure range covered was from 30 to 75 lb. per sq. in.; rate of mud flow was 100 to 600 c.c. per sec. (corresponding to about 0.5 to 2.5 ft. per sec. mean linear velocity).

TABLE 1.—*Filtration Constants of Muds Used in Radial Filtration*
Determined in linear filters at 80° F.

Sample	Density, Lb. per Gal.	Viscosity, Sec., Marsh	v	s	μ, Cp.	R', Reciprocal Darcys
1. Gulf Coast No. 1	9.5	36	0.127	0.833	0.89	8.8×10^5
2. No. 1, 0.1 per cent sodium tannate added	9.5	30	0.127	0.833	0.89	1.0×10^6
3. No. 1, 1.0 per cent salt added	9.5	44	0.222	0.850	0.91	2.2×10^5
4. 6.5 per cent bentonite	8.6	37	0.11	0.833	0.89	3.6×10^6
5. Gulf Coast No. 2, weighted	15.0	36	0.81	0.50	0.89	7.8×10^4

Results.—The results of a representative series of runs (on the untreated Gulf Coast mud) are shown in Fig. 3, where are plotted cumulative volume of filtrate against time for each of the pressures and rates of mud flow.

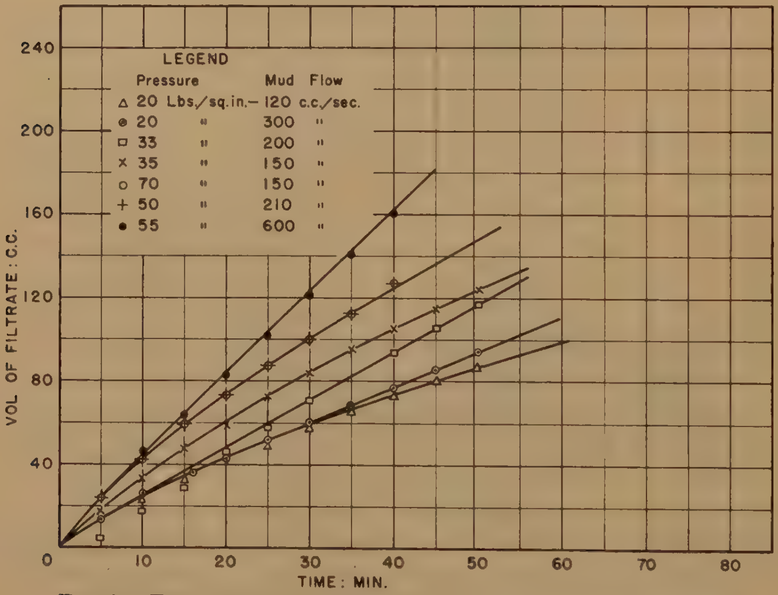

FIG. 3.—FILTRATION OF UNTREATED MUD IN CYLINDRICAL FILTER.

In all runs, it was observed that the rate of filtration became constant after a short time. It was found that the value of the constant rate attained in any particular run depended on the pressure, rate of mud flow, and character of the mud. From these results, it is apparent that constant rate of filtration obtains because the thickness of the filter cake becomes constant; as fresh cake tends to form, it is carried away by the hydraulic action of the mud stream.

Correlation

Since the volume of filtrate-time curves for all runs become linear soon after filtration is initiated, only the steady state of constant rate of filtration will be considered.

The equation for filtration against a plane medium with no mud agitation is given by[11]

$$\frac{V}{A} = \sqrt{m\theta + c^2} - c$$

in which

$$m = \frac{2P^{1-s}}{\mu v R'(1 - s)}$$

$$c = \frac{A\rho' f(P)}{vR'P^s}$$

where V = cumulative volume of filtrate, c.c.,
A = area of filter, sq. cm.,
θ = time, sec.,
P = pressure drop across cake, atm.,
μ = viscosity of filtrate, centipoise,
v = ratio of volume of filter cake, c.c., to volume of filtrate, c.c.,
s = a compaction function of the cake,
R' = a function of the resistivity (reciprocal permeability) of the cake
$\rho' f(P)$ = a function of the resistance of the filtering medium (detailed discussion in ref. 11).

In this equation, c is ordinarily negligible.

Empirically, it was found that the steady-state filtration rate $\left(\frac{dV}{d\theta}\right)_c$ of these runs varied linearly with the square root of the rate of axial mud flow Q, and with the square root of the m value of the mud as determined by routine evaluation; or

$$\left(\frac{dV}{d\theta}\right)_c = c_1\sqrt{Qm}$$

The plot of $\left(\frac{dV}{d\theta}\right)_c$ against $\sqrt{Qm}$ for all runs made is given in Fig. 4.

Since the rate of filtration varies directly as the filtering area a, this may be written

$$\frac{\left(\frac{dV}{d\theta}\right)_c}{a} = c_2\sqrt{Qm}$$

It should be pointed out that pressure, cake compaction, viscosity of filtrate, and cake resistance are included in the m term; consequently, when it is desired to apply this equation to a particular case, it is only necessary to obtain the m value from a single run made on the "wall-building tester" at the desired temperature and pressure differential. Where this is not feasible, an approximation may be made, as will be shown later.

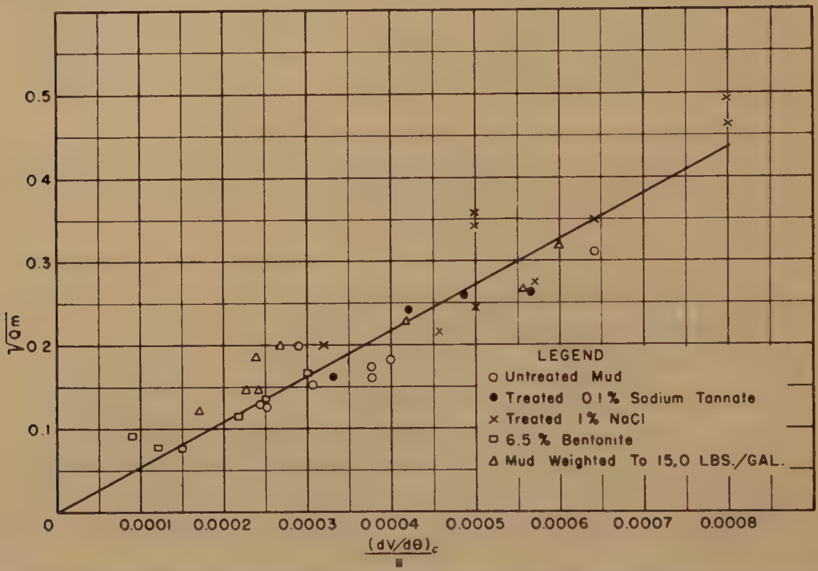

FIG. 4.—CORRELATION OF RATE OF FILTRATION AT STEADY STATE, WITH RATE OF MUD FLOW AND PROPERTIES OF MUD.

Variation of Filter Diameter

The effect of one important variable, size of filter, has not been investigated experimentally. Accordingly, the extension of this equation to filters of other sizes has been made by dimensional analysis.

Recalling the equation

$$\frac{V}{A} = \sqrt{m\theta + c^2} - c$$

it will be seen that m has the dimensions $(\text{length})^2(\text{time})^{-1}$. The dimensions of Q are $(\text{length})^3(\text{time})^{-1}$, so that the dimensions of Qm are $(\text{length})^5(\text{time})^{-2}$.

In the equation

$$\frac{\left(\frac{dV}{d\theta}\right)_c}{a} = c_2\sqrt{Qm}$$

the left-hand member has the dimensions $(\text{length})(\text{time})^{-1}$. For a dimensionally sound equation, both members must have the same dimensions. In order to satisfy this condition, a term having the dimensions (length)^3 must be introduced into the denominator of the term under the radical. This is done by writing the equation

$$\frac{\left(\frac{dV}{d\theta}\right)_c}{a} = k\sqrt{\frac{Qm}{M^3}}$$

where M is the hydraulic radius of the filter; or, in the case of annular flow between a pipe and the inner wall of the filter, the hydraulic radius of this annulus.

The introduction of the hydraulic radius in this manner appears to be satisfactory, inasmuch as it is almost equivalent to the quite reasonable assumption that, for a given mud, the same rate of filtration per unit area will be established in any size filter when the velocity of axial mud flow is such that the same fluid pressure drop per unit length is maintained.

Although, strictly speaking, the hydraulic radius should be based on the inner diameter of the filter cake itself, no appreciable error is introduced by use of the inner diameter of the filtering medium, since at moderate rates of mud flow the thickness of the cake is relatively small.

Evaluation of k

Inspection of the filter at the completion of each run indicated a large accumulation of mud cake at the ends of the filter, through which, at steady-state conditions, only a small part of the total filtrate passed. In the evaluation of the constants in these equations correction should be made for these end effects. This has been done by assuming that the effective length of the filtering surface was approximately two-thirds the actual length. Although it is recognized that this assumption will introduce some error into the computations, the equation is probably sufficiently precise for practical purposes.

From the plot given in Fig. 4, for the filter used,

$$\frac{\left(\frac{dV}{d\theta}\right)_c}{a} = 0.0019\sqrt{Qm}$$

Introducing the hydraulic radius M, this becomes:

$$\frac{\left(\frac{dV}{d\theta}\right)_c}{a} = 0.0017\sqrt{\frac{Qm}{M^3}}$$

Although centimeters-grams-seconds were used in evaluating k, its value will remain unchanged as long as all variables are expressed in the same system of units. However, m is customarily expressed in square centimeters per second, while the other variables are usually determined in English units. Accordingly, a more convenient form of the equation for practical application is

$$\frac{\left(\frac{dV}{d\theta}\right)_c}{L} = 0.12D\sqrt{\frac{Qm}{M^3}}$$

in which the terms have the following units:

$\left(\frac{dV}{d\theta}\right)_c$ = rate of filtration, barrels of filtrate per hour,
L = length of filter, ft.

or

$\frac{\left(\frac{dV}{d\theta}\right)_c}{L}$ = rate of filtration, barrels of filtrate per hour per foot of filter,
D = internal diameter of filter, in.
Q = rate of axial mud flow, bbl. per min.,
M = hydraulic radius of annular space between filter and pipe, in.,
m = filtration constant of mud under existing conditions, sq. cm. per sec.

Application

In the application of this equation to particular cases, it is found convenient to employ graphical methods to facilitate computation.

Computation of m.—Since the c value in routine evaluation is usually negligible, a plot of V at given lengths of time against m may be employed to obtain m values for muds run in the usual type of wall-building tester at 100 lb per sq. in. Such a plot is given in Fig. 5.

Although m should preferably be determined at the pressure differential and temperature existing in the well, it is possible to obtain a fair approximation of this value from routine wall-building tests at 100 lb. per sq. in. and atmospheric temperature.

The value of s, the cake-compaction function, has been determined from a large number of runs on Gulf Coast muds. From the averages (s decreases with increasing mud weight) of these values, Fig. 6 has been constructed. Computation has further been simplified by introduction of normal Gulf Coast formation pressures[14] to give differential pressures between the hydrostatic head of mud and formation pressures directly. Thus, the pressure-correction factor for m for mud of any weight at any depth is readily found.

Because of the erratic variation of m with temperature, only approximate rules can be formulated. Generally, in the Gulf Coast area, increased temperature will cause m to double for every 5000 ft. of hole drilled with unweighted muds, and with heavily weighted muds m will double every 10,000 ft. of hole.

Computation of $\left(\frac{dV}{d\theta}\right)_c$.—Graphs may be constructed for a given hydraulic radius, showing the relation of m to $\left(\frac{dV}{d\theta}\right)_c$ at various rates of mud flow. Such a graph, for the particular case of 6-in. drill collar in 8¾-in. hole is shown in Fig. 7. The use of this is obvious.

Distance of Penetration of Filtrate.—The relation of distance of penetration to time for various rates of filtration is shown in Fig. 8, with the permeable formation assumed to have a porosity of 25 per cent, and 80 per cent of the reservoir fluid assumed to be displaced by the filtrate.

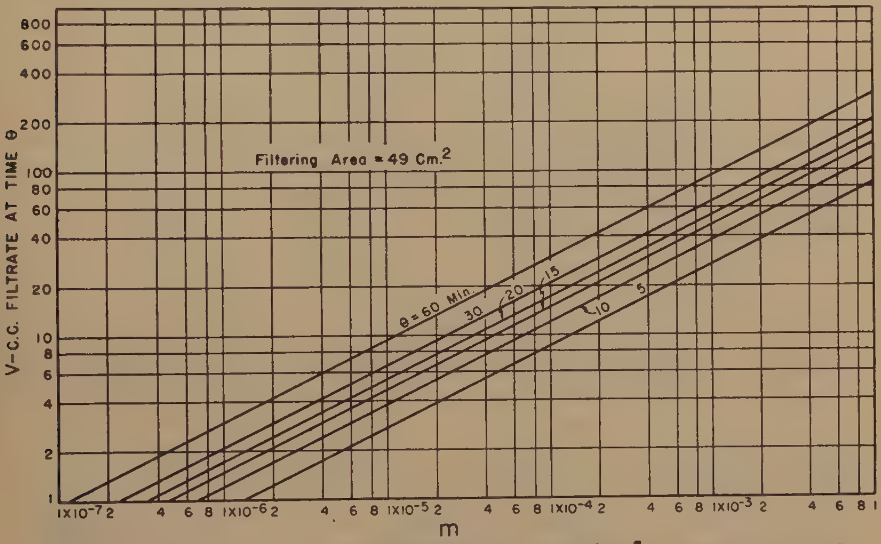

FIG. 5.—RELATION OF VOLUME OF FILTRATE AT TIME θ TO m VALUE OF MUD IN COMMERCIAL FILTER.

Example of Use

To illustrate the use of the equation, an example met in practice may be cited. It is desired to compute the distance of penetration of the filtrate into a producing sand approximately 6000 ft. deep, the hole being bottomed at this depth. The data are:

Size of hole: 8¾ in.
Size of drill collar: 6 in.
Pump: 20-in. stroke, 7¾-in. liner, 37 cycles per min.
Mud: weight: 9.8 lb. per gal.; filtration: 29 c.c. in 30 min. in wall-building tester at 100 lb. per sq. in. and 80° F.

The rate of mud circulation, assuming 85 per cent volumetric efficiency for the pump, is readily computed to be 12 bbl. per minute.

From Fig. 5, the m value of the mud is 2×10^{-4}. By reference to Fig. 6, the pressure-correction factor is found to be 1.2; the temperature-

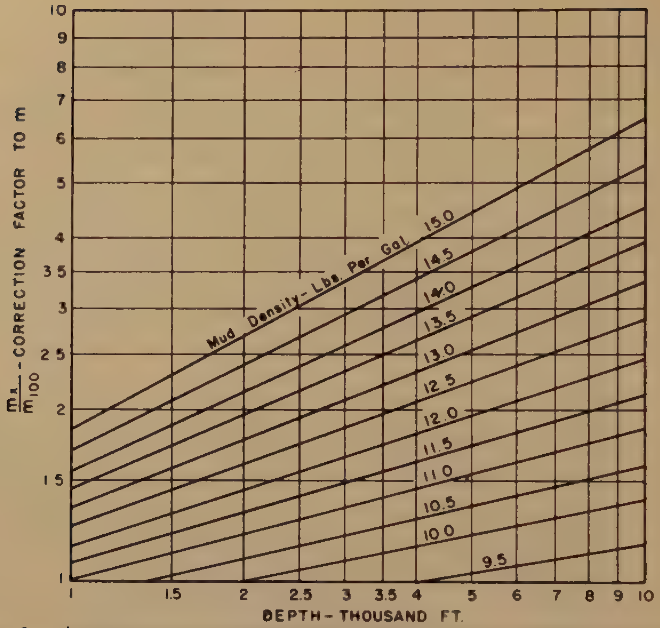

FIG. 6.—APPROXIMATE CORRECTION FACTORS DUE TO PRESSURES FOR *m*.
Normal Gulf Coast formation pressure only.

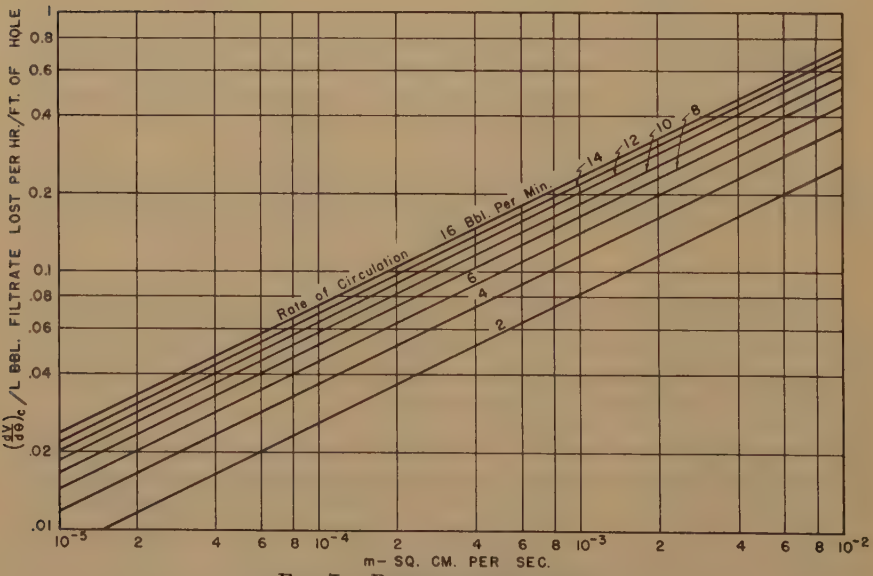

FIG. 7.—RATE OF FILTRATION.
8¾-inch hole, 6-inch drill collar.

correction factor, from the empirical rule cited previously, may be assumed to be 2.4 (from the depth of hole, $^{6000}/_{5000} \times 2$). The corrected m then is 5.8×10^{-4}.

From Fig. 7, the rate of filtration is found to be 0.15 bbl. per hr. per foot of hole. Assuming that one volume of filtrate displaces the reservoir fluid from five volumes of sand, the distance of penetration is found from Fig. 8. Thus, when $\theta = 4$ hr., Z, the distance of penetration, $= 1.9$ ft.; when $\theta = 8$ hr., $Z = 2.9$ ft.; when $\theta = 24$ hr., $Z = 5.4$ ft.; when $\theta = 168$ hr., $Z = 14$ ft. and when $\theta = 720$ hr., $Z = 30$ feet.

FILTRATION WITH NO MUD FLOW

When there is no axial mud flow, as when drill pipe is withdrawn from open hole, the hydraulicking effect of the mud stream is obviously absent.

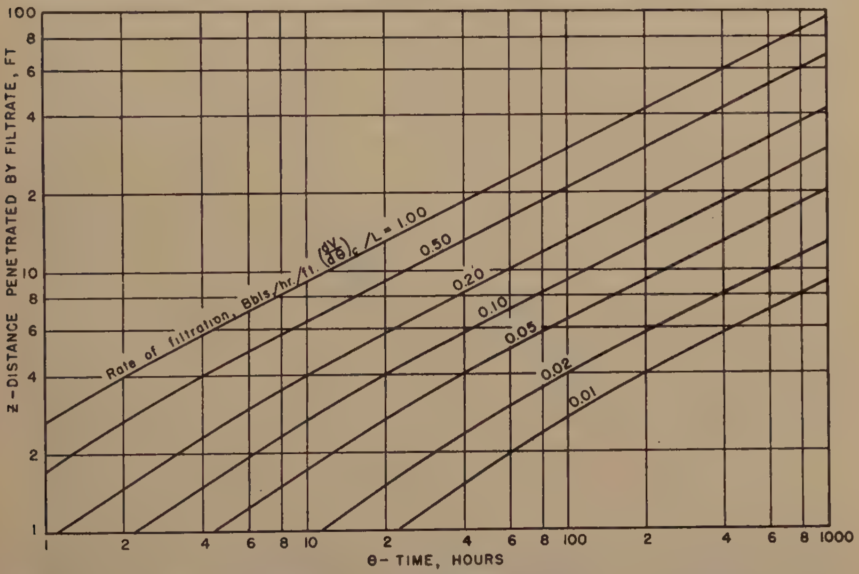

FIG. 8.—DISTANCE OF PENETRATION OF PERMEABLE STRATA BY FILTRATE ASSUMING 25 PER CENT POROSITY AND 80 PER CENT FLUID DISPLACEMENT.

In this case, the area of the filter cake exposed to the mud becomes smaller as the cake becomes thicker, until finally, when the hole is completely filled with filter cake, the exposed area becomes zero.

Filtration Equation.—By a mathematical treatment similar to that used in the development of the filtration equation for the simple laboratory filter with no mud agitation, it is possible to arrive at an approximate relation for the "radial flow" case. This involves only the factors involved in the "linear flow" case, and of course, the dimensions of the cylindrical filter. This relation is

$$V + \left(\frac{\pi r_0^2 L}{v} - V\right) \ln \left(1 - \frac{vV}{\pi r_0^2 L}\right) + \frac{4\pi L \rho' f(P)}{R' P^s} = \frac{4\pi L P^{1-s}}{\mu R'(1 - s)} \theta$$

where r_0 = radius of cylindrical filter, L = length of cylindrical filter, and the other symbols are as previously defined.

It can be shown that this equation reduces to that of the "linear" case when the cake thickness is small compared to the radius of the filter.

Experimental.—The filtration curve of a Gulf Coast mud, with no axial mud flow, as compared with the calculated curve, is shown in Fig. 9. In calculating the theoretical curve, the values of the constants were obtained from simple "linear" evaluation; the deviation of the theoretical from the observed is due to the neglect of the resistance of the porous cylinder.

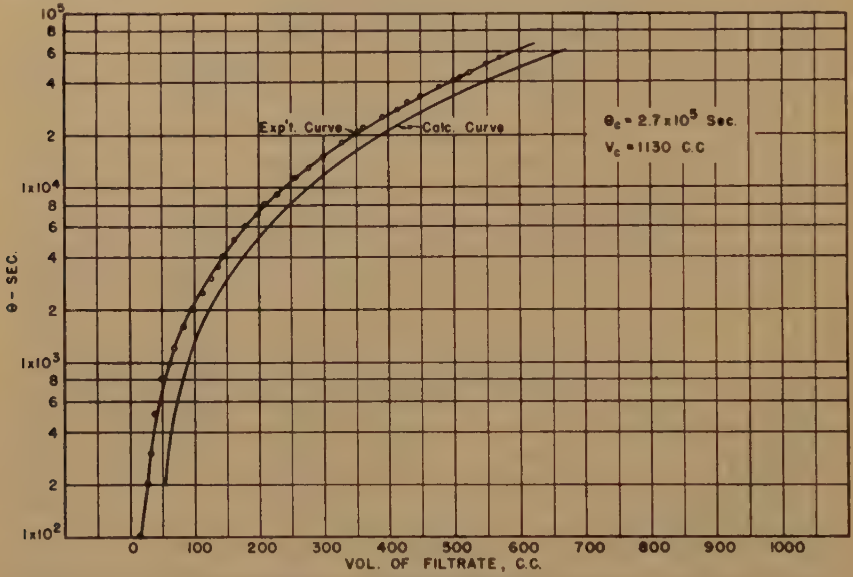

FIG. 9.—RADIAL FILTRATION OF GULF COAST MUD WITH NO AXIAL MUD FLOW.

Complete Filling of Hole with Filter Cake.—From this equation, it is possible to obtain the relations giving the time necessary for complete filling of the hole with filter cake, as well as the cumulative value of filtrate at this time. Denoting these values by the subscript c, it is found that

$$\theta_c = \frac{\mu R'(1-s)r_0^2}{4vP^{1-s}}$$

$$= \frac{r_0^2}{2mv^2}$$

$$V_c = \frac{\pi r_0^2 L}{v}$$

For the Gulf Coast mud previously illustrated, v was found to be 0.13; the time for complete filling of the hole by the cake would be

$$\theta_c = 6.6 \times 10^6 \text{ sec., or } 1.8 \times 10^3 \text{ hr.}$$

For a mud of poor quality, the time for complete filling may be considerably less; for a mud from West Texas having $m = 5.0 \times 10^{-2}$ and $v = 0.15$, under the same conditions,

$$\theta_c = 4.7 \times 10^4 \text{ sec., or 13 hr.}$$

It follows that complete filling of the hole during normal operations is liable to occur only with muds of unusually bad filtration characteristics.

Conclusions

It is evident that infiltration may present a serious problem in certain cases; a study of the factors involved suggests the best remedial measures.

Since the dimensions of hole and rate of mud circulation are usually fixed by drilling conditions, variation of these to reduce filtration is impractical. Mud control obviously is the solution.

While each mud presents a different problem with regard to securing optimum filtration properties, certain generalities can be stated; (1) that dispersing agents reduce filtration, while coagulating agents increase filtration; and (2) that the predominance of particles of colloidal dimensions ordinarily is conducive to low filtration rates.

Acknowledgment

The author wishes to acknowledge his indebtedness to Dr. W. B. Lewis and Mr. R. W. Jenkins, of the Production Research Department of the Humble Oil & Refining Co., for the execution of the greater part of the experimental work.

References

1. P. H. Jones and E. C. Babson: Amer. Petr. Inst., Drill. and Prod. Practice (1935) 22.
2. R. A. Silent: *Oil and Gas Jnl.* (1936) **35,** No. 1, 72.
3. W. A. Sawdon: *Petr. Engr.* (1936) **7,** No. 5, 27.
4. Drilling Mud (Baroid Sales Dept.,): *a*, April 1937; *b*, May 1938.
5. W. L. Horner: Oil Weekly (1935) **78,** No. 3.
6. E. N. Dunlap: *Trans.* A.I.M.E. (1938) **127,** 215.
7. R. J. Schilthuis: *Trans.* A.I.M.E. (1938) **127,** 199.
8. R. H. Fash: *Bull.* Amer. Assn. Petr. Geol. (1934) **18,** 265.
9. C. P. Bowie: U. S. Bur. Mines *R.I.* 3354 (1937).
10. P. H. Jones: Amer. Petr. Inst., Drill. and Prod. Practice (1937) 24.
11. M. Williams and G. E. Cannon: *Oil Weekly* (1938) **90,** No. 2, 25.
12. B. F. Ruth, G. H. Montillon and R. E. Montonna: *Ind. and Eng. Chem.* (1933) **25,** 76, 153.
13. B. F. Ruth: *Ind. and Eng. Chem.* (1935) **27,** 708, 806.
14. G. E. Cannon and R. C. Craze: *Trans.* A.I.M.E. (1938) **127,** 31.

DISCUSSION

(M. T. Halbouty presiding)

R. W. Wilson,* Houston, Tex.—Mr. Williams has presented a timely contribution to the art of drilling wells. It is a method of interpretation that makes much more valuable the standard static mud-filtration test that has already proved extremely useful and describes an application of this test to many of the problems of drilling, logging and completing oil and gas wells.

The results on the distance to which water from drilling muds may penetrate permeable bodies are startling and certainly emphasize the importance of maintaining drilling muds that will allow a minimum amount of filtrate to penetrate the formations.

The empirical relationship that was developed to estimate the steady rate of filtration is simple but takes into account most of the important variables related to the problem except the texture—toughness and brittleness—of the cake deposited, which is notably absent from consideration. Mud cakes vary widely in texture and it may be expected that these properties will affect the rate of erosion of the cake by the mud stream, which is important in determining the equilibrium filtration rate.

W. E. Winn,† Dallas, Texas.—In several instances we believe the filtrate from drilling muds has served to give erroneous results from drill-stem tests. We believe that this filtrate has not only pushed back into the capillaries, forcing the oil ahead of it, but that also it has caused the small amount of bentonite present in most southwest Texas sands to swell and partly plug the hole. Consequently, when the tool is opened on a drill-stem test, the oil is delayed so long by the necessity of breaking down the oil-water interface, opening the partly plugged capillary channels, and discharging the filtrate from the sands, that the tool is closed before the oil reaches the hole.

Have you studied the effect of filtration of drill-stem tests? Also, have you studied the filtration effect on the fluid contents of cores?

M. Williams (author's reply).—Although I have no positive knowledge of any case in which excessive filtration has prevented oil from entering the hole on a drill-stem test, that this could and has happened is a distinct possibility. In this connection, the difficulty of bringing in wells in many fields may be mentioned. In many cases, wells cannot be brought in until much water, presumably lost from the drilling mud, has been swabbed out of the producing formation.

The displacement of the original fluids from cores is apparently quite a different process from the radial flow of filtrate into strata around the well bore; the factors affecting contamination of cores by the filtrate have not been evaluated. Regardless of what other factors may be operative, however, this contamination would be expected to decrease with decreasing mud filtration as determined in routine "wall-building" tests.

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Detection of Radioactive Cement in Cased Wells

By Lynn G. Howell* and Alex Frosch*

(Galveston Meeting, October 1939)

In a previous article[1] we have described a technique for measuring the relative intensities of gamma rays from the radioactive elements occurring naturally in geological formations along the walls of a borehole. The apparatus consisted of two Geiger-Müller tubes mounted inside a pressure-tight chamber. Each counter tube was coupled separately to an amplifier and a frequency meter at the surface by means of a multiconductor cable upon which the chamber was suspended. The output currents of the two frequency meters were recorded on a photographic paper as the chamber was moved in the hole. These traces showed remarkable correlation with the geologic formations, as evidenced by comparison with commercial electrical logs.[2] Owing to the penetrating power of the gamma rays, logs may be taken in both open and cased boreholes.

The apparatus has recently been changed somewhat. One of the counter tubes has been removed and a stage of amplification has been added inside the chamber. This arrangement seems to give a more favorable signal-to-noise ratio and satisfactory logs can be now made in cased holes and also in open holes as previously. Briefly described, the chamber moving in the hole is made of 3½-in. drill pipe and is about 10 ft. long. There is an additional extension about 2 ft. long at the top, inside which cable connections are made. The Geiger-Müller tube is mounted inside the bottom end of the chamber. Above this is the vacuum-tube amplifier with its batteries and transformer. In the top part of the chamber, small 45-volt batteries are mounted, which in part supply the high voltage for the counter tube. Additional voltage is supplied from the surface through the multiconductor cable upon which the chamber is suspended. Also, the output of the transformer in the single-stage amplifier is coupled to another single-stage amplifier at the surface through this cable. The surface amplifier is coupled to the Thyratron-controlled frequency meter, the tank circuit of which consists of a one megohm resistor across which is a bank of condensers varying in

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* Geophysics Department, Humble Oil and Refining Co., Houston, Texas.

[1] L. G. Howell and A. Frosch: *Geophysics* (1939) **4** (2), 106.

[2] C. and M. Schlumberger and E. G. Leonardon: *Trans.* A.I.M.E. (1934) **110**, 237.

discrete steps from 4 to 28 microfarads. The output current of the frequency meter, which varies with the number of pulses per unit time, is recorded on a photographic paper as the chamber moves in the well. Thus a continuous record of the pulse "frequency," which is proportional to the radioactivity of the environs of the Geiger-Müller tube, is recorded as a function of depth.

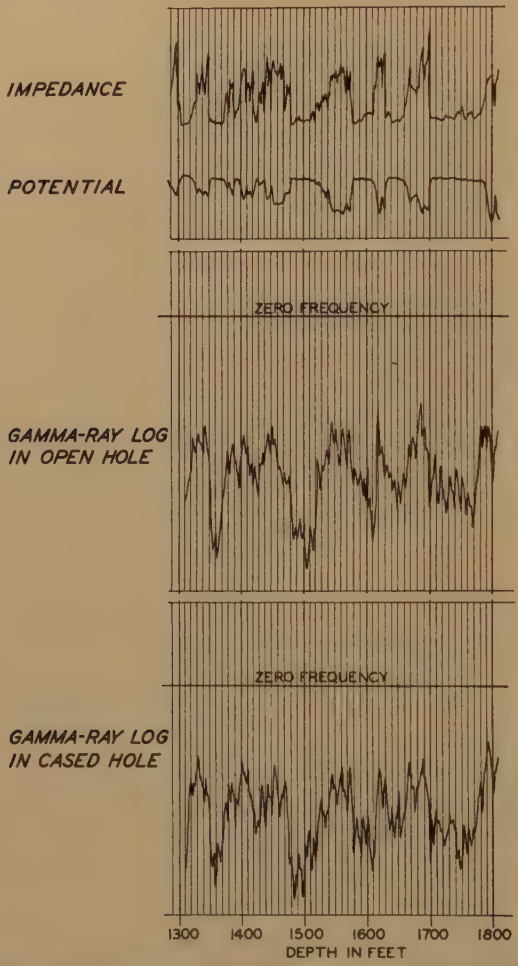

FIG. 1.—COMPARISON OF GAMMA-RAY LOGS AND ELECTRICAL LOGS IN THE UPPER SECTION OF A GULF COAST WELL.

Sample open-hole and cased-hole gamma ray logs are compared with commercial electrical logs in Figs. 1 and 2. The depths are plotted in the horizontal direction. The electrical log taken in open hole is shown at the top in the two figures; next is the gamma-ray log taken in open hole; and finally, at the bottom, is the gamma-ray log in cased hole. In the customary fashion, the impedance increases in the upward direction;

the potential curve is arbitrary, showing relative changes of the potential of the moving electrode with respect to a fixed electrode at the surface, the potential of the moving electrode increasing positively in the upward direction; the radioactivity curves show increases in the downward direction. The zero-frequency line for each gamma-ray log is shown above the curve. This line is never touched in practice, of course, since there is always a background count from the apparatus and environs even though a formation with no radioactivity could be realized. No attempt is made to evaluate the background count because not only the apparatus but also the mud in the hole and the casing contribute to the background in a fashion that would be very difficult to determine. There are chance

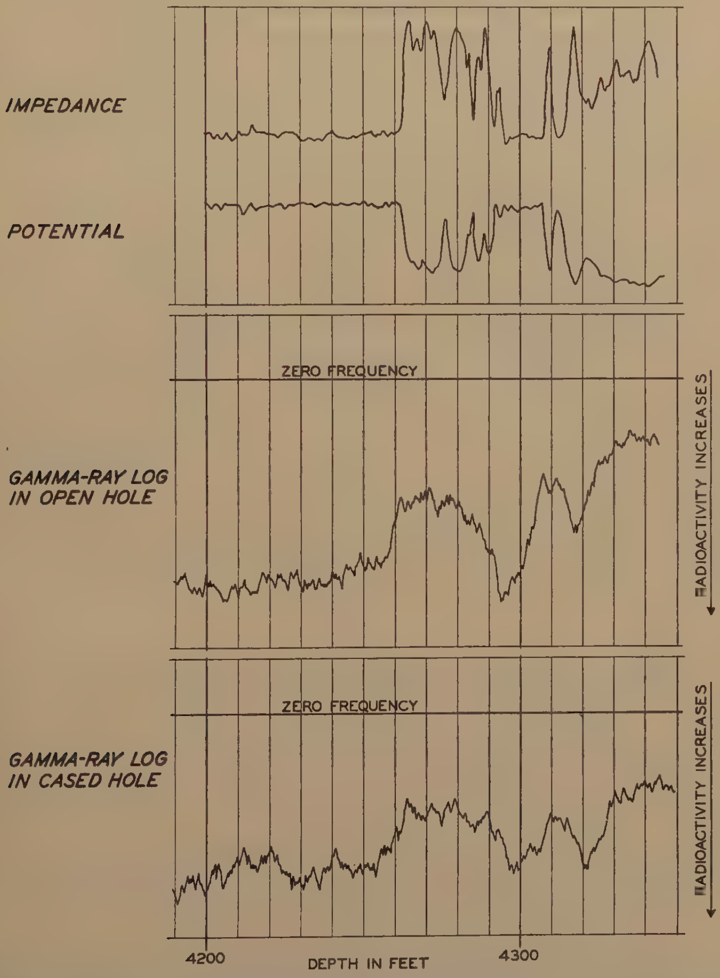

FIG. 2.—COMPARISON OF GAMMA-RAY LOGS AND ELECTRICAL LOGS IN THE PRODUCING SECTION OF A GULF COAST WELL.

variations in the gamma-ray curves, the magnitudes of which decrease with the time constant[3] of the tank circuit of the frequency meter. The gamma-ray curves in Fig. 1 were taken with a smaller time constant in the tank circuit and with a greater speed of the chamber (the spacing of the depth lines bears no relation to the speed of the chamber). The speeds were of the order of 25 ft. per min. and 9 ft. per min., respectively. The gamma-ray logs in Fig. 1 were taken at a depth shallow enough in the casing such that there is little likelihood of any cement behind the casing. Comparison of the absolute magnitudes of the open-hole and the cased-hole logs reveals that there is some absorption by the casing; the outstanding features of the log are retained. The logs in Fig. 2 were taken in the bottom producing section of the well. The casing was set at 4305 ft. (drillers' measurements). Lateral shifting of the patterns of the logs show that there is a discrepancy of a few feet in the various depth measurements of the logs. The interesting point is that below the neighborhood of 4305 to 4310 ft., the two gamma-ray logs, which were both recorded in open hole, follow each other closely in magnitude, and above this region there is an upward shift of the cased-hole gamma-ray log. This indicates a decrease in gamma ray intensity caused by the absorbing effect of the casing and the cement back of the casing. Except for the shift, the broad pattern is maintained.

As in the earlier investigation, the gamma-ray logs show a remarkable correlation with the electrical logs. In general, the sands show up as radioactive "lows" and the shales as radioactive "highs."

Cement Detection

The gamma-ray logging apparatus has been used in connection with another interesting problem. The presence of cement behind the casing in a well can be detected by mixing a radioactive substance with the cement before it is pumped into the well and afterward running a gamma-ray survey.

In our work, we have mixed carnotite, containing of the order of 10 per cent uranium oxide, with the cement. Fig. 3 shows gamma-ray surveys made in three wells in which the cement was treated with carnotite. These wells were all situated in the same Gulf Coast field and all were cemented with 230 sacks of cement or cement-sand mixture. In well No. 1 probably between 100 and 200 lb. of carnotite was added to the cement. The ore was distributed throughout the cement except for two batches of 50 or 60 sacks each. In these logs radioactivity increases in the upward direction. The sensitivity is lower than that shown in the previous figures; also the speed of the chamber in the hole can be made as high as 50 ft. per min. There is a sharp upward break on the top log at a depth of about 5090 ft., which would indicate the top of the cement at that point. In well No. 2, 25 lb. of carnotite was added to the first few sacks of cement pumped into the well. The radioactivity

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[3] L. I. Schiff and R. D. Evans: *Rev. Sci. Instr.* (1936) **7**, 456.

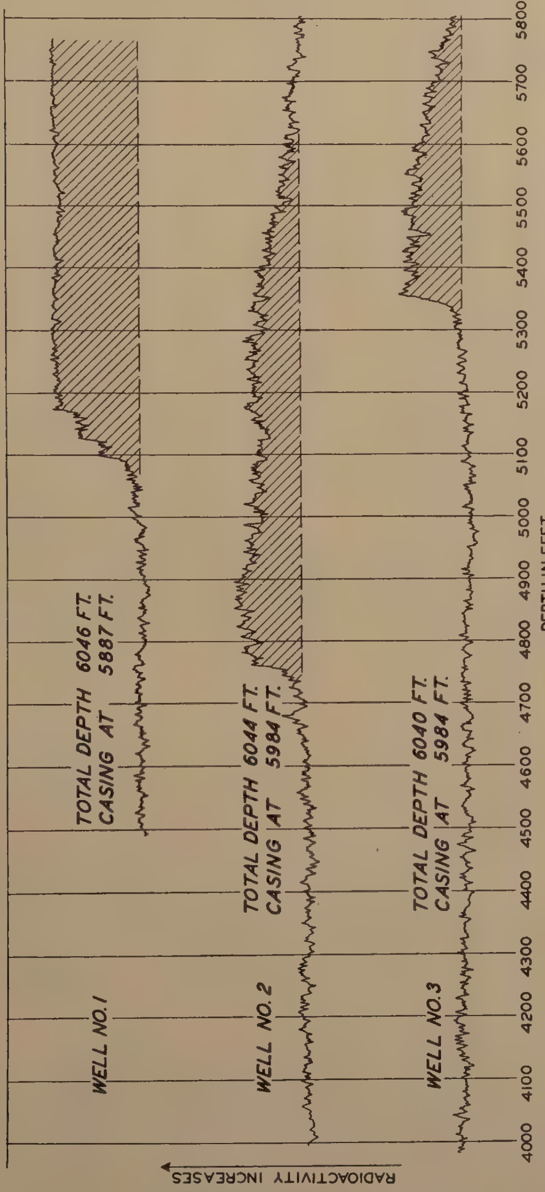

FIG. 3.—GAMMA-RAY LOGS IN WELLS HAVING RADIOACTIVE CEMENT BEHIND THE CASING.

remains high for several hundred feet after the break upward, which would indicate that the carnotite and probably the cement to which it was added do not remain in a lump intact as they are pumped down the hole and up the outside of the casing. In well No. 3, 36 lb. was added to the first batch of cement. The surprising fact in this well is the small height of the column of cement behind the casing. Although there is about the same amount of casing and cement in wells 2 and 3, yet there is a difference of about 600 ft. in the height of the cement in the two wells. Also, although more carnotite was added to the cement in well No. 3 than in No. 2, the shaded area on log No. 2 is greater than that on log No. 3. Since the area under the curve gives a qualitative measure of the ore detected, there is an indication that some of the ore, and probably some of the cement, was side-tracked somewhere in well No. 3.

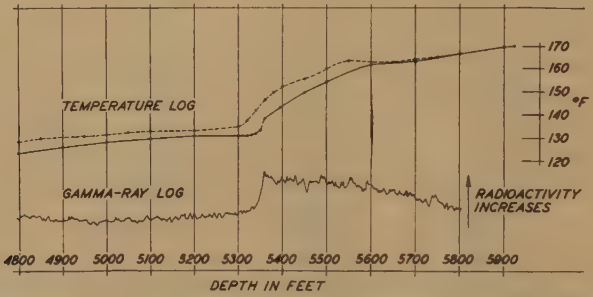

FIG. 4.—COMPARISON OF TEMPERATURE AND GAMMA-RAY LOGS IN WELL No. 3, TO DETERMINE THE TOP OF THE CEMENT BEHIND THE CASING.

To find whether the upswing in the gamma-ray logs represents the actual top of the cement, a temperature survey was run in well No. 3; it is possible to detect cement when it is setting, by the heat generated in the process. Fig. 4 shows a comparison between the gamma-ray log and the temperature log. The continuous temperature line was obtained going in the hole, and the broken line was obtained coming out. Although there is a lag between the two curves, the average of the two points, at which the temperature breaks up, agrees as well as could be expected with the break on the gamma-ray curve. It is interesting that

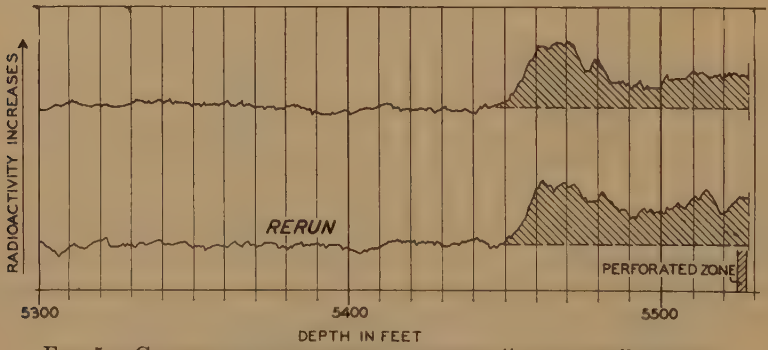

FIG. 5.—GAMMA-RAY LOG USED IN LOCATING "SQUEEZED" CEMENT.

a sharper break is obtained on the gamma-ray curve than on the temperature curve.

In a so-called squeeze cement job, the cement is pumped out through perforations behind the casing after the casing has been set and cemented. It is of interest to investigate where the cement is squeezed, since, as a rule, an attempt is made to seal off water or gas sands by means of this second cementing. There may be difficulties in getting information concerning the location of the cement from a temperature survey. For example, it is usually necessary to make a survey soon after the mud has been circulated in the hole during the drilling out of the cement left inside the casing; this mud circulation, of course, disturbs the temperature distribution along the casing; also, the old cement behind the casing has an insulating effect.

By using the gamma-ray method we have been able to detect the cement squeezed behind the casing. Fig. 5 shows a survey in a well in which three stages of squeezing were performed. In each of the first two stages, 35 sacks of cement was pumped down; in the third stage, 17 sacks. About one-half pound of carnotite per sack of cement was mixed in with the cement. Two curves are shown, one being a repeat of the other. These logs indicate that a sizable body of the cement, the position of the cement being represented by the shaded area, moved up the casing about 60 or 70 ft. from the perforated zone, indicated at the lower part of the diagram.

Fig. 6 shows a survey made in another well, in which the cement had been squeezed through the casing in the zone indicated. The concentration of ore was again one-half pound of carnotite per sack of cement; 61 sacks were squeezed out. In this well, the cement remained near the zone of perforation. The magnitudes of the changes in radioactivity cannot be compared with those in the other squeeze job because the sensitivity is different.

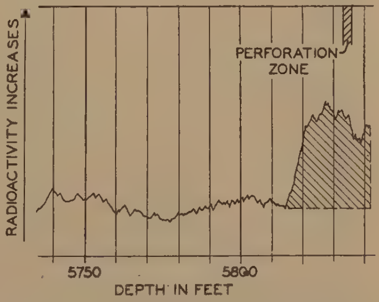

Fig. 6.—Gamma-ray log used in locating "squeezed" cement.

Conclusion

The gamma-ray well-logging apparatus has reached the stage at which it can be put to use in both open and cased holes in a variety of problems. An interesting application is the detection of radioactive cement just described. The method is more flexible than the temperature method in that it is not necessary to make the survey while the cement is still setting up; also, the circulation of mud has no disturbing effect, and, finally, the concentration of ore added to the cement can be varied to give a sufficiently large change in gamma-ray intensity even though the treated cement may be pumped behind the old cement. However, it must be remembered that the locations of formations behind radioactive cement cannot be found with the gamma-ray method described, since the feeble radioactivity of the formations is masked by the strong radioactivity of the cement.

Other obvious applications of the method in wells have been suggested, such as the detection of radioactive acidizing agents, plugging agents, gels, and so on. The general idea of introducing radioactive cement in wells was advanced by Mr. S. E. Buckley, of this company.

Chapter II. Engineering Research

Visual Studies of the Flow of Air-water Mixtures in a Vertical Pipe

By Sylvan Cromer* and R. L. Huntington,† Members A.I.M.E.

(San Antonio Meeting, October 1938)

The need for a clear understanding of the physical nature of the flow of gas-liquid mixtures in vertical pipes is ever becoming more apparent. This type of flow is encountered when gas and oil are produced from a well; when water is removed from gas wells with siphon lines and when liquids are elevated by means of air or gas lift. Although a number of investigators[1-7] have published data on the flow of gas-liquid mixtures, in only a few cases has the experimental setup been devised to permit visual study. In the fields of heat transmission, such as the boiling of liquids and the study of the critical phenomena of the hydrocarbons, researchers have been able to throw additional light on heretofore unexplainable happenings through actual observation in glass apparatus. This investigation was therefore undertaken in order to obtain qualitative as well as quantitative results for air-water flow.

EXPERIMENTAL APPARATUS AND PROCEDURE

The flow column used in these tests was made of standard 2-in. pipe and was approximately 98 ft. in height. Pyrex observation sections 2 ft. long having the same internal diameter as the wrought-iron pipe were placed at 14-ft. intervals in the column. The bottom of the tube was cut off square and terminated in the mixing chamber. No perforated nipple or footpiece of any kind was used. To the top of the column was fastened a semicircular return bend having a 4-ft. radius.

The flow column was supported by a standard cable-tool drilling derrick (Fig. 1) into which were built observation platforms at each Pyrex section.

The data given herein are taken in part from the thesis presented by Sylvan Cromer in partial fulfillment of the requirements for the Degree of Master of Science in Engineering at the University of Oklahoma in 1937. Manuscript received at the office of the Institute Nov. 4, 1938. Issued as T.P. 1080 in Petroleum Technology, August 1939.

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† Professor, Chemical Engineering, University of Oklahoma, Norman, Okla.

[1] References are at the end of the paper.

Compressed air for the test was taken from the University lines and reduced in pressure with a weight and lever type regulator (Fig. 2). A control valve was used to regulate the rate of flow into the mixing tank. The air passing into the flow tube was measured with a standard recording orifice flowmeter. A two-pen thermometer recorded the air and water temperatures.

The water circulated by gravity from a tank mounted at the top of the derrick through a control valve and orifice flowmeter into the mixing tank. Here it was mixed with the air and after passing upward through the flow tube was discharged back into the tank at the top of the derrick. By proper manipulation of the two control valves, any air-water ratio at any desired submergence could be obtained. A water pump was used only for charging the system and not for the circulation of water.

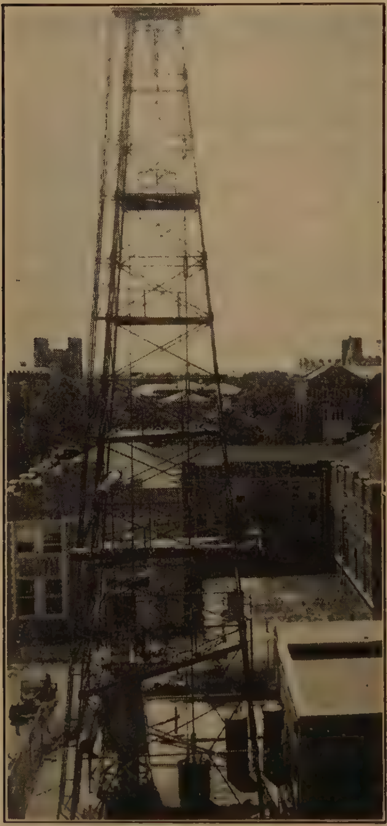

Fig. 1.—Flow column supported by drilling derrick.

The control valves, recording flowmeters, gauges and thermometer are grouped on one panel so that the entire operation of the flow tube could be conveniently handled by one operator (Fig. 3).

Discussion of Results

The original data obtained during this investigation are presented in (Fig. 4), showing the characteristic curves for various air-water ratios and flow rates, as well as the efficiency curve for the different rates. The efficiency was based on the ratio of the actual work done in lifting the water to that of the theoretical work done by the isothermal expansion of the gas throughout the height of the column. Calculations show that the kinetic energy of the stream was negligible for the high rates compared with the expansive energy of the air.

Shaw[3] calls attention to four points, significant in the operation of an air-lift pump: (1) the point of no flow due to a deficiency of air; (2) the point of maximum efficiency; (3) the point of maximum yield; (4) the point of no flow due to an excess of air.

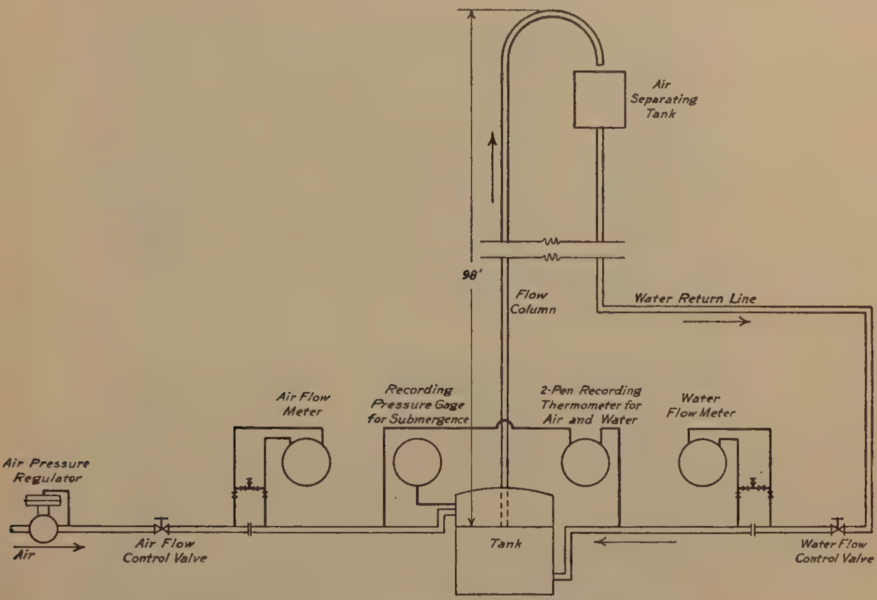

FIG. 2.—APPARATUS FOR STUDYING FLOW OF MIXTURES OF GAS AND LIQUIDS IN A VERTICAL PIPE.

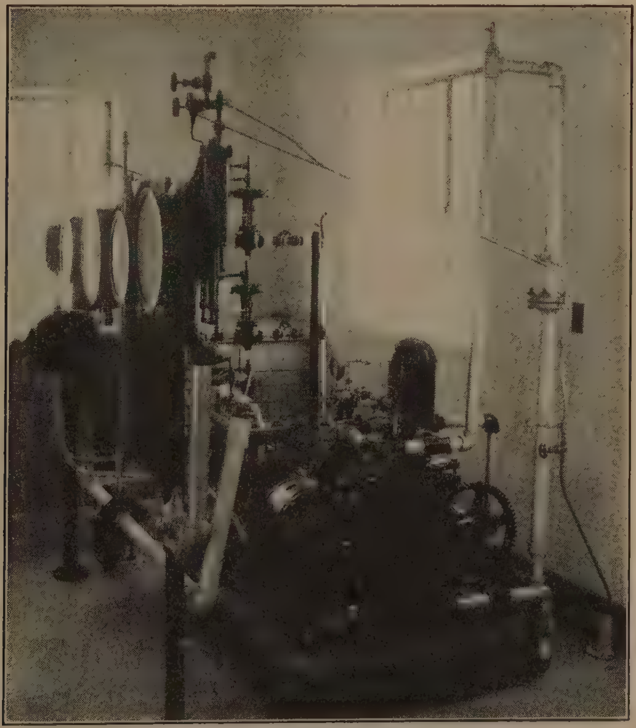

FIG. 3.—CONTROL AND METER PANEL.

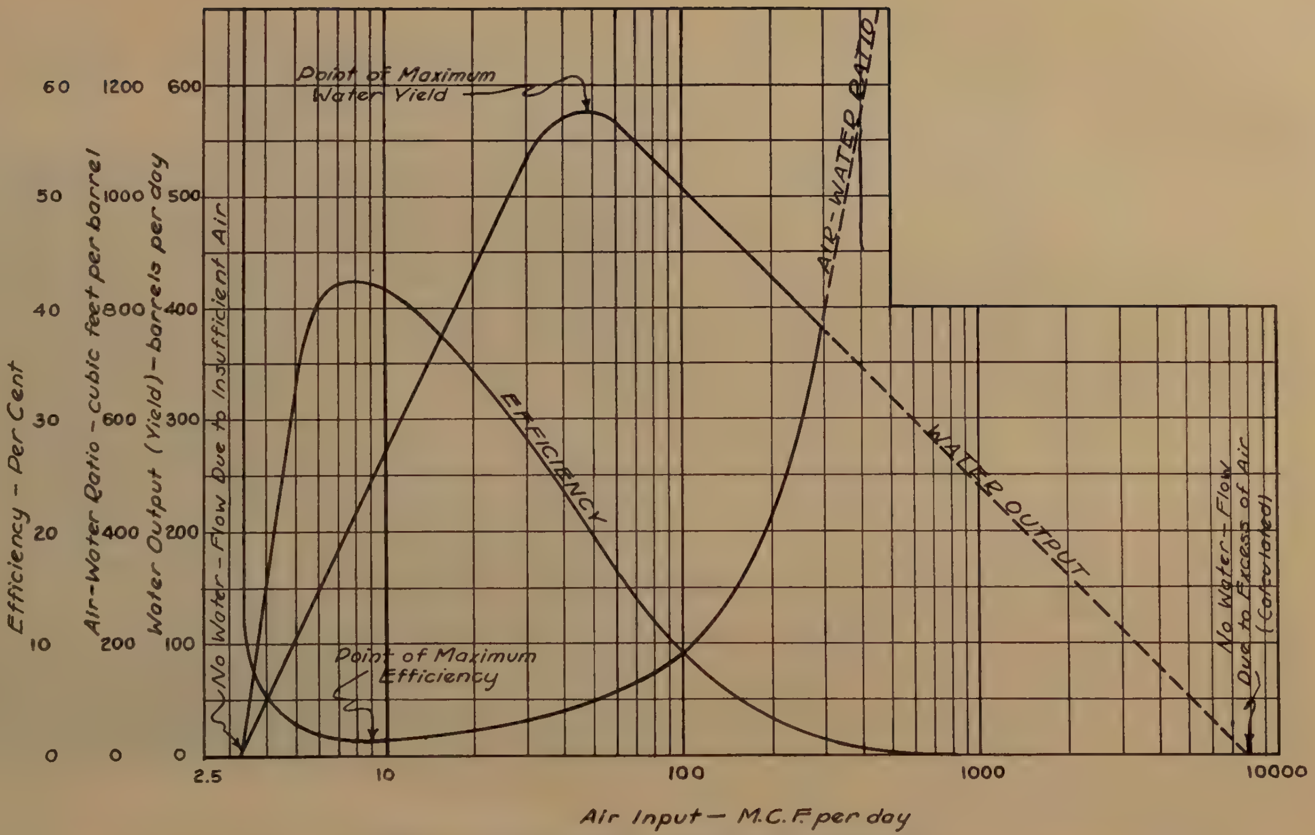

FIG. 4.—CHARACTERISTIC CURVES FOR AIR-WATER LIFT.
Flow tube 98 ft. high; 2.04 in. inside diameter. Submergence 32.61 ft., or 33.17 per cent. Water and air 80° F.
See comment on page 90.

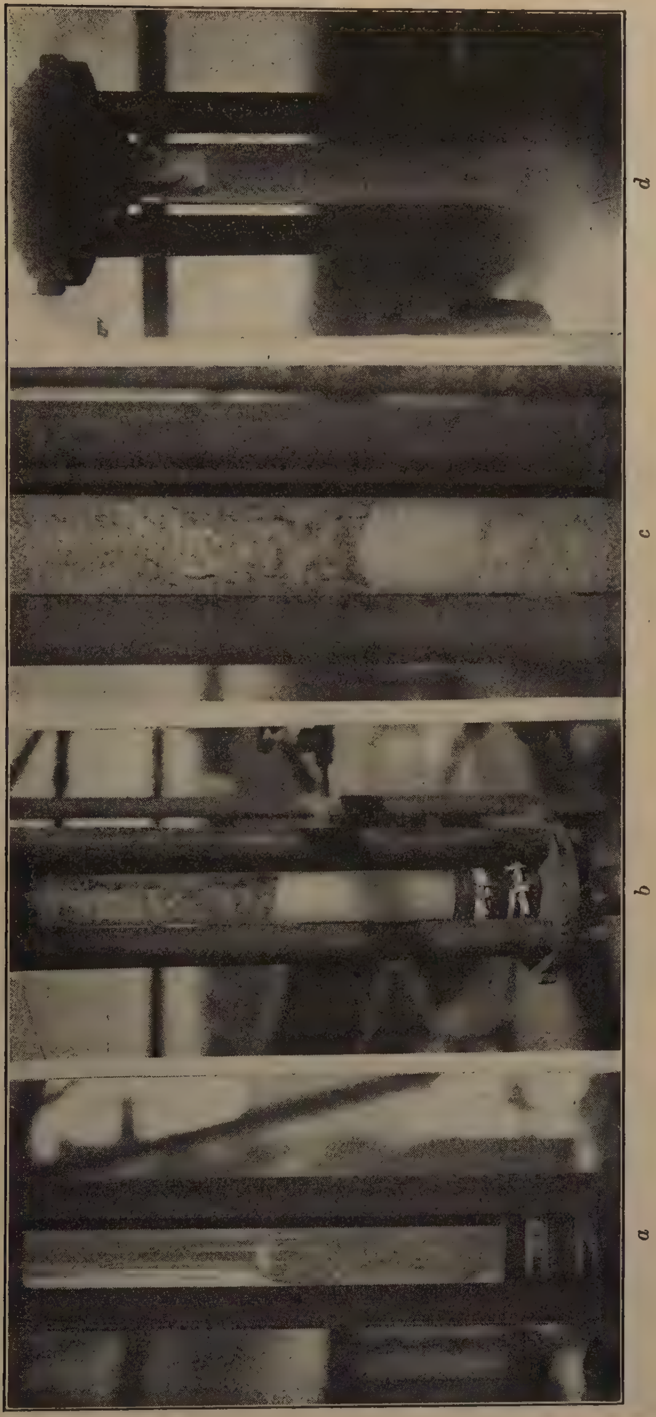

FIG. 5.—NO WATER FLOW BECAUSE OF INSUFFICIENT AIR.
a, 2 ft. from base of column. *c*, 61 ft. from base of column.
b, 32 ft. from base of column. *d*, top of column 96 ft. from base.

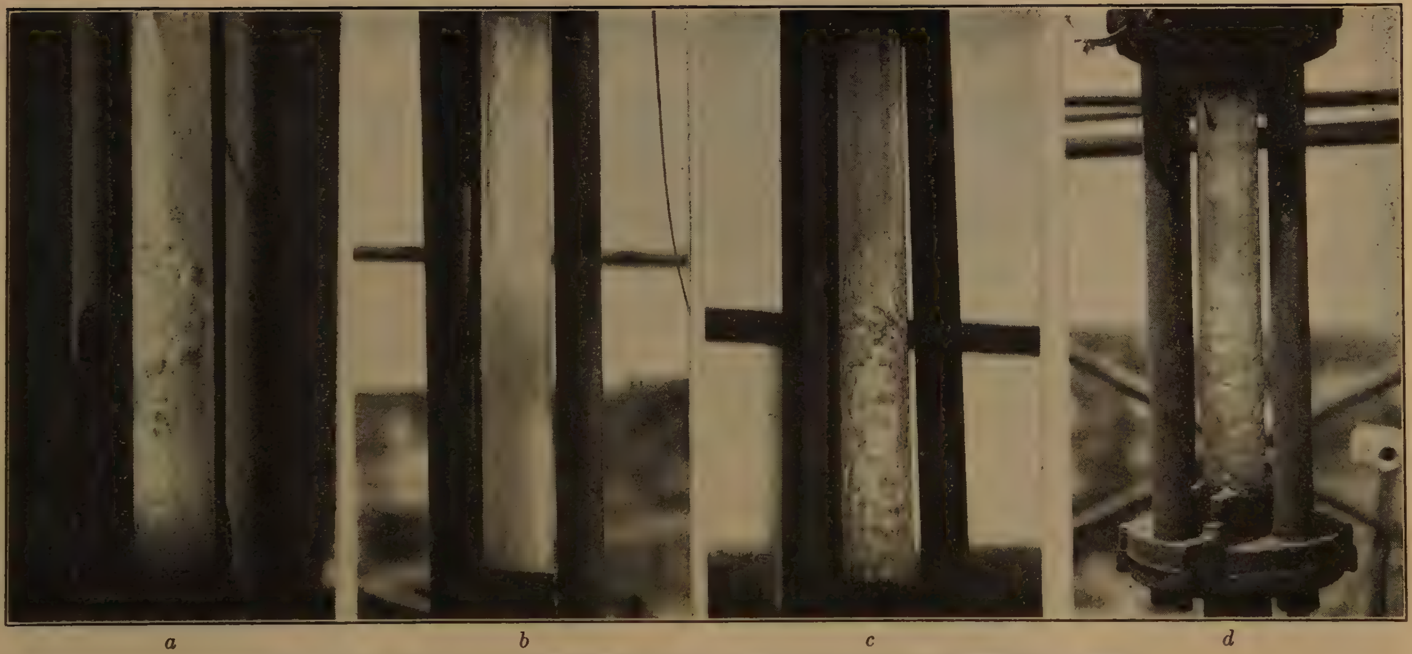

FIG. 6.—MAXIMUM FLOW EFFICIENCY; AIR-WATER RATIO 30.3 CUBIC FEET PER BARREL.
a, 2 ft. from base of column.
b, 32 ft. from base of column.
c, 61 ft. from base of column.
d, top of column 96 ft. from base.

As the air-water ratio needed to produce one of these points in any flow column is dependent upon submergence, these tests were made at a constant submergence equivalent to 32.8 ft. of water, an arbitrarily chosen level.

Point of No Flow Due to Insufficient Air.—If the air enters the bottom of a flow column at an extremely low rate, it will merely rise to the surface of the liquid in small bubbles. Any bubbles over 1 in. in diameter formed small semispheres which were flat on the bottom. At slightly higher air rates, the bubbles merged before passing the first and second observation sections, forming short bullet-shaped slugs. An air-input rate of 3000 standard cubic feet per day produced well-formed bullet-shaped slugs (Fig. 5*a*) in the first observation section 2 ft. above the inlet. At 16 ft., a number of small, round air bubbles were observed following each bullet-shaped slug. At 32.6 ft. all of the water between these slugs was aerated but each slug produced higher aeration, as may be observed in Fig. 5*b*. At 60.8 ft., the appearance was much the same except that the portion of aerated water between the slugs had almost reached the froth stage. The bubbles were all of a fairly uniform diameter and were arranged in symmetrical rows inside the column (Fig. 5*c*). The top of the aerated column may be seen in the glass 93.6 ft. above the inlet in Fig. 5*d*. The mixture was frothy in appearance at this point.

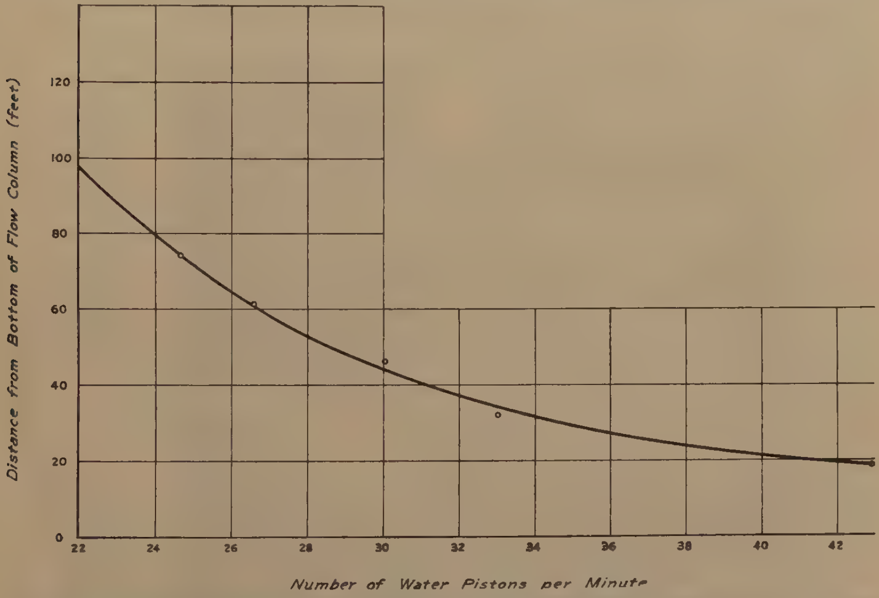

FIG. 7.—CURVE SHOWING NUMBER OF PISTONS OF WATER PER MINUTE PAST ANY GIVEN POINT ON THE FLOW COLUMN.

Length of column 98 ft.; 2.04 in. inside diameter. Air-water ratio 28.7 cu. ft. per barrel (point of maximum efficiency).

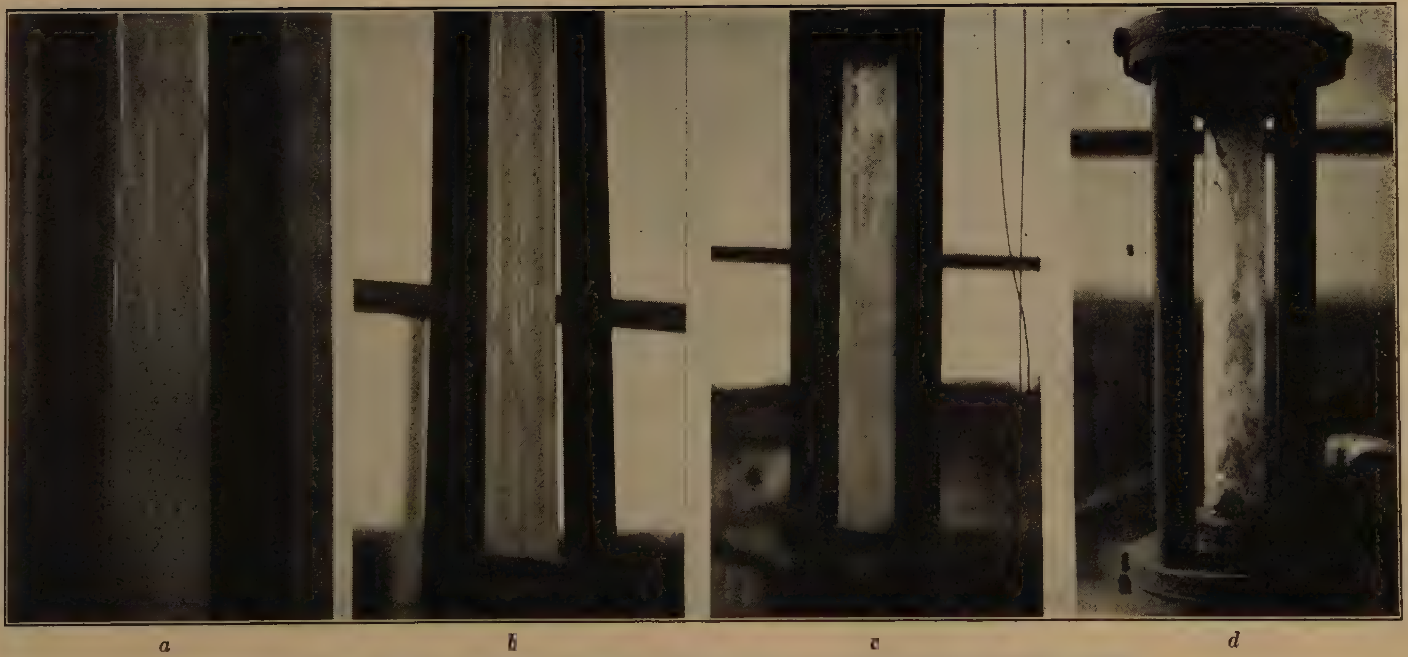

FIG. 8.—MAXIMUM WATER-FLOW RATE; AIR-WATER RATIO 60.3 CUBIC FEET PER BARREL.
a, 2 ft. from base of column.
b, 32 ft. above base of column.
c, 61 ft. above base of column.
d, top of column 96 ft. from base.

Point of Maximum Efficiency.—The minimum air-water ratio of 37 cu. ft. per barrel was reached with an air-input rate of approximately 9000 cu. ft. per day (Fig. 4). In the bottom observation section (Fig. 6*a*), the air was observed entering at a uniform rate and no slugs or pistons were apparent. At 16 ft. up, however, owing apparently to slippage, alternate pistons of water and air were seen. As the mixture ascended the column, these short pistons apparently merged to form longer ones. The air piston was at all times surrounded by an annular ring of water that flowed downward along the sides of the pipe (Figs. 6*b* and 6*c*). The merging of the pistons just mentioned seemed to be timed uniformly, as it was possible to count them as they passed each observation station. The pistons of water became progressively longer as the mixture ascended the column. Likewise, the water velocity apparently increased toward the top of the tower. The number of water slugs passing each section per minute is shown in Fig. 7.

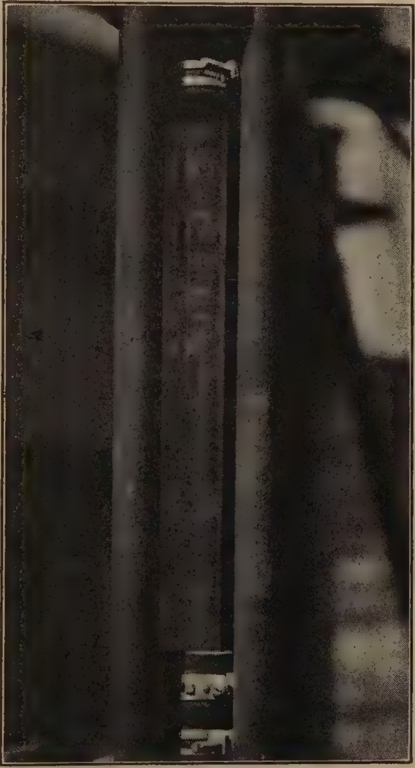

Fig. 9.—Annular flow at high air-water ratios.

Point of Maximum Water Flow.—When the air rate was increased to 45,000 cu. ft. per day the maximum yield of 580 bbl. of water was obtained with an air-water ratio of 60.3 cu. ft. per barrel. The water and air was observed passing the lower sections as a uniform mixture (Fig. 8*a*), but at about 32.6 ft. (Fig. 8*b*) pistons started forming and this type of flow prevailed to the top of the column (Figs. 8*c* and 8*d*). The pistons passing each observation glass were short and were moving too rapidly to be counted, as was done in the previous tests. The downward flow of the water around the air pistons was no longer prevalent. Because of the absence of this reversal of direction of flow, it might seem at first thought that this should be the point of maximum efficiency. The difference apparently is due to the increased friction losses caused by the higher velocities, occurring with the maximum yield.

Point of No Flow Due to an Excess of Air.—As the air rate was increased above 35,000 cu. ft. per day the flow of water diminished. The pistons gradually disappeared and the water appeared to be traveling both as droplets suspended in the air stream and in an annular ring along the sides. A further increase caused the core of air to carry less and less water until it became comparatively free of it and the water rippled upward along the sides of the flow tube (Fig. 9) in the annular ring reported by Gosline.[2] When the air rate was increased sufficiently, the friction loss produced by the air flowing through the pipe became greater than the hydrostatic head of water. This obviously prevented water from entering the pipe and a second condition of no liquid flow was reached.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Messrs. A. L. Harrington, Renn Rothrock, Toney Vaughn, G. M. Bell, Ben Hill, Harold Bone and Sidney Walker, all engineering students, for their assistance in the construction and operation of the experimental apparatus.

REFERENCES

1. G. J. Davis, Jr. et al.: Investigation of the Air-Lift Pump. Univ. Wisconsin *Bull.* 450.
2. J. E. Gosline: Experiments on the Vertical Flow of Gas-liquid Mixtures through Vertical Pipes. *Trans.* A.I.M.E. (1936) **118**, 156.
3. S. F. Shaw: Some Observations on Principles Involved in Flowing Oil Wells. *Trans.* A.I.M.E. (1930) **86**, 220.
4. L. C. Uren, P. P. Gregory et al.: Flow Resistance of Gas-oil Mixtures through Vertical Pipes. *Trans.* A.I.M.E. (1930) **86**, 209.
5. H. D. Wilde, Jr. and T. V. Moore: Experimental Measurement of Slippage in Flow through Vertical Pipes. *Trans.* A.I.M.E. (1931) **92**, 296.
6. J. Versluys: Mathematical Development of the Theory of Flowing Oil Wells. *Trans.* A.I.M.E. (1930) **86**, 192.
7. J. Versluys: Some Principles Governing the Choice of Length and Diameter of Tubing in Oil Wells. *Trans.* A.I.M.E. (1931) **92**, 293.

DISCUSSION

(*E. P. Hayes presiding*)

R. L. HUNTINGTON.—This work brings out clearly the importance of making visual observations of various physical processes and phenomena whenever it is feasible to do so. We have recently attempted to obtain density gradients on a mixture of air and water flowing vertically through a 100-ft. column equipped with several 1-in. quick-closing Merco stopcocks. These stops could be closed instantaneously during a flow run and the water in each section weighed. Had the visual tests been taken before the attempt was made to obtain the density gradients, it would have been much easier to explain the erratic density gradients that come with the piston-type flow.

T. A. POLLARD, Whittier, Calif.—I wonder if any attempts were made to approximate the velocities of flow in the glass tube at the rates of maximum flow and maximum efficiency? The mean starting velocity at the base of the tube, as related to the pressures involved, would be of interest. Also, the over-all average velocity of all fluids passing through the tube would be of some interest. It appears to me that a relatively close determination of the latter velocities might be obtained by using the familiar $Q/A = V$ equation (Q = volume of fluid flowing per unit of time; A = cross-sectional area of the tube; V = mean velocity at the cross section). The use of dye at the time of the experiments might have given a general idea of the average velocities; i.e., the length of time required for dyed water to flow from the bottom of the tube to the top would have indicated the over-all average liquid velocities. Having determined the proper velocities for maximum flow and maximum efficiency, some application of the data might then be made to gas-lift problems.

S. F. Shaw,* San Antonio, Tex.—This paper by Cromer and Huntington is important in pointing the way toward an analysis of air-lift flow, which as yet is but imperfectly understood. The practical side of gas-lift flow lies in answering two questions: (1) How much compressed gas at a given pressure is required to lift one barrel of a given liquid through a pipe of given length and diameter? (2) What is the capacity of a pipe of given length and diameter for a liquid of a given character, when operating under a given bottom-hole flowing pressure? If these questions could be answered for any and all conditions, the practical side would be covered. Several attempts have been made to analyze the problem and yet no satisfactory answer has been forthcoming, and we are entirely dependent upon actual tests covering a given range as a guide for a similar operation.

Observations on the character of the flow in the pipe are important. The work done by Cromer and Huntington at Oklahoma University, and that by Gosline at the University of California, although covering a very short range of possible operations, is already beginning to throw some light on this subject.

Under very low velocity and in small diameter of flow pipe, the air is seen to move upward as a piston; under high velocity, the air moves as a cylinder through the central portion of the pipe while the liquid is dragged along the surface of the pipe in the form of ripples or annular rings. Does this action account for the low efficiencies under low submergence percentage?

The experiments carried out at the University of Oklahoma were conducted through a small pipe of very short length compared to oil-field practice. The velocity at the top under condition of maximum efficiency was 5.5 ft. per second; under condition of maximum capacity the velocity was 25.6 ft. per second, and under condition of no flow due to insufficient gas the velocity was 1.6 ft. per second. There is doubt as to the fourth condition of no flow taking place at rate of 8,000,000 cu. ft. of air per day. The writer's experience would suggest that this would take place at less than 1,000,000 cu. ft. per day under the conditions of submergence and diameter and length of pipe used. These velocities appear to cover a wide range, and yet much wider ranges are covered in oil-field operations in deep wells.

The lifting efficiency of 42.5 per cent at point of maximum efficiency, with submergence of 33.2 per cent, is high for a pipe of 2-in. diameter, compared to which the lifting efficiency of 17 per cent at point of maximum capacity is low. But these figures are higher than Gosline's, who used pipe 1 in. in diameter. This brings out the point that lifting efficiency is greater for a given submergence as the diameter of the pipe increases, a fact that has been observed by the writer in many tests on oil wells. Perhaps this will be explained eventually by the difference in the character of the flow when using pipes of different diameters.

A careful study of this subject would result from the visual study of flow through pipes ranging from ½ in. to perhaps 6 in. in diameter, and in length from perhaps 10 to 1000 ft., and under flowing pressures ranging from 1 lb. to 500 lb. per sq. in. The greater lengths, perhaps, would have to be studied in a mine shaft.

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* Consulting Engineer, Westgate Oil Co.

Messrs. Cromer and Huntington are to be commended for their studies as presented, especially for their moving pictures, shown at the San Antonio meeting, and it is hoped that this paper will stimulate the desire for a more extended series of similar observations.

S. Cromer (authors' reply).—Dr. Huntington and I both believe that because of the slippage of water down the sides of the column any dye injected at the base of the column as suggested by Mr. Pollard would be so diffused that measurement of velocities by this method would be impractical. However, as the actual mechanics involved in putting the die into the flow stream would be simple, I believe the results might justify trying the method. A great deal might be learned about the nature of the slippage even if quantitative data could not be obtained.

Inlet and exit velocities may be calculated by the equation $Q = AV$ because the quantity of liquid and vapor and the pressure at both ends are known. Intermediate velocities are more difficult to obtain because the ratio of water to air is variable. This, along with intermediate pressures, is needed to determine the density of the mixture. The flow column, equipped with quick-closing valves, described in Dr. Huntington's discussion, was built in an attempt to determine these intermediate velocities.

Mr. Shaw's comment regarding the fourth condition (no flow due to an excess of air) is correct. This condition, as explained in the paper, is obtained when the friction loss due to vapor passing through the flow column is equal to the liquid pressure. This prevents any liquid from entering the base of the flow column. As a sufficient quantity of air was not available to obtain this point experimentally, it was calculated by use of Weymouth's equation. It is equal to 803,000 cu. ft. per day, not 8,030,000 as shown. The error was made in plotting the curve (Fig. 4).

Experiments have been made at Oklahoma University using a 1-in. flow tube in which the entire range of air-water ratios from no flow due to insufficient air to no flow due to an excess of air at several constant submergences were studied. The shapes of the actual curves were similar to one shown in our paper. Data on curves obtained by these experiments may be obtained from the author's graduate thesis, "The Flow of Air-water Mixtures in Vertical Pipes," from the Oklahoma University Library.

Flow of Gas-liquid Mixtures through Consolidated Sand

By Holbrook G. Botset*

(Galveston Meeting, October 1939)

Experiments performed in this laboratory on the flow of gas-liquid mixtures through unconsolidated sands have been described and discussed in an earlier paper.[4] In these earlier experiments a definite relationship was found between the liquid saturation of a sand and its permeability to the liquid or gas phase. Furthermore, the nature of the sand, the permeabilities of the sands over a range between 17 and 260 darcies, appeared to have a negligible effect upon the saturation-permeability relation. Likewise experiments indicated that the viscosity of the liquid, or the substitution of an immiscible liquid for the gas phase, had only a very slight effect on the permeability-saturation relation. This conclusion has since been definitely confirmed by the experiments of M. C. Leverett[3] on the flow of oil and water through unconsolidated sands. The sands used by Leverett were of very low permeability (between 6.8 and 1.04 darcies), while the oil-water viscosity ratio varied between 90 and 0.057.

Since the sands that constitute petroleum reservoirs are largely consolidated, although of widely varying degrees of consolidation, it was desirable to extend the experiments on gas-liquid mixtures to consolidated sand. In the study of consolidated sands additional variables are involved, but for the initial experiments the only new variable to be introduced was the cementing material.

Experimental Procedure

A comparatively limited assortment of sandstones was available for the selection of the experimental material. Of these, the Nichols buff sandstone appeared to be most suitable. It gives no visual evidence of any bedding planes, it has a firm structure, permitting easy handling, and its permeability is about 0.5 darcy. Its only disadvantage is the fact that it contains an appreciable amount of ferric oxide which, for experiments involving water, will hydrate and reduce the permeability. This

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Manuscript received at the office of the Institute April 28, 1939. Issued as T.P. 1111 in Petroleum Technology, November 1939.

* Gulf Research and Development Co., Pittsburgh, Pa.

[4] References are at the end of the paper.

disadvantage was eliminated by thoroughly leaching the core with hydrochloric acid, thus dissolving all the ferric oxide, as well as any calcareous matter present; which made the core very stable chemically.

In order to minimize the importance of experimental errors, a core of appreciable size was required, the dimensions being: length, 136.6 cm. (4.48 ft.); diameter, 10.2 cm. (4.0 in.). The core was accurately cut to these dimensions by a local stonecutter. This core was sealed, by means of pitch, into an insulating sheath so designed that electrical contact was made to the core around its entire circumference by means of bronze piezometer rings, through which the pressures also were measured. These pressure rings, details of which are shown in Fig. 1, are placed at 15.0-cm. intervals along the core, the two terminal rings being 7.4 and 9.2 cm. from the ends. The remainder of the apparatus was the same as that used in the experiments on unconsolidated sands.[7] The assembled apparatus is shown in Fig. 2. In order to prevent gradual plugging of the core by the large volume of water that would be flowing through it in the course of the experiments, a pre-filter was placed in the flow line immediately preceding the core, as may be seen in Fig. 2. This pre-filter consisted of a section of Nichols buff sandstone 4 in. in diameter and about 1 in. thick sealed in a brass holder. Any substances in the water that might plug

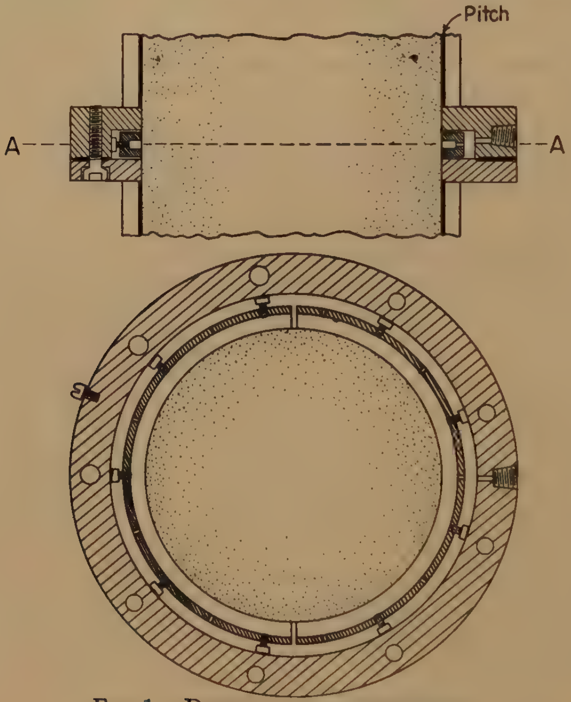

FIG. 1.—DESIGN OF PRESSURE RINGS.

the sand were thus caught by this pre-filter,[1] with the result that permeability measurements made on the sand column after months of experiments showed no decrease in the original permeability, the final over-all permeability being 0.500, while the original averaged 0.495 darcy. The supply tank was filled with freshly distilled water made slightly conducting by the addition of 3 grams of K_2SO_4 per liter.

Before the core could be filled with water, it was necessary to replace all the air in the system, including that in the pores of the core, by carbon dioxide. This was done by flowing carbon dioxide slowly through the system for several days and also repeatedly compressing the gas in the system and valving it to atmospheric pressure. When it was thought that the air had been entirely replaced by carbon dioxide, unsaturated water was flowed through the system under a slight pressure, dissolving the carbon dioxide and ultimately filling the system with dead liquid. Flow was continued until the constancy of the resistances of the eight sections of the core indicated that there was no more free gas in the system. A permeability measurement was then made and the results agreed very closely with the results of earlier permeability measurements made on other samples of the same sandstone. The permeabilities for the eight sections of the core were, respectively, 0.457, 0.489, 0.531, 0.516, 0.493, 0.485, 0.511, 0.480, averaging 0.495 darcy for the entire core. This variation of about 16 per cent in permeability along a 5-ft. section of a very homogeneous sandstone gives some indication of the minimum variations of permeability to be expected in producing sands. The

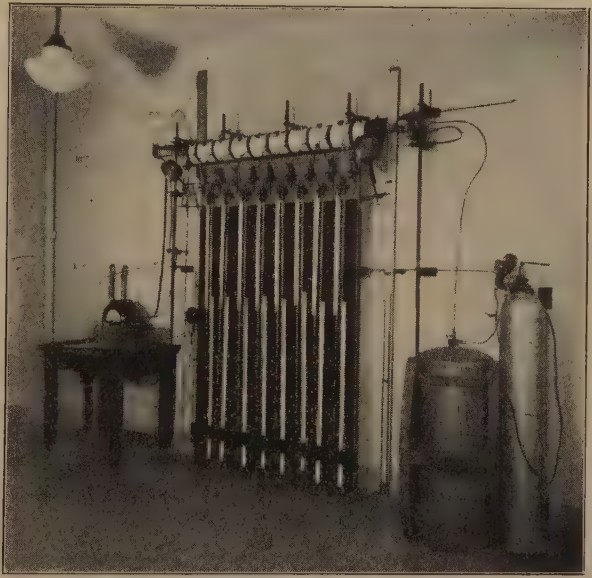

FIG. 2.—ASSEMBLED FLOW APPARATUS.

porosity of the sandstone was 21.8 per cent and the pore volume of the core 2414 cubic centimeters.

The experimental procedure for establishing the relationship between saturation and gas and liquid permeabilities was exactly the same as that used in the study of unconsolidated sands.[4,5]

In the initial experiments the saturation pressure was low (7 to 10 lb. per sq. in. gauge) and the fluid was flowed through the sand at a very slow rate in order to determine the value of the equilibrium saturation,[4] which was found to be 90 per cent. This agrees closely with the result obtained by a different method on a very small core sample of this same sandstone, discussed elsewhere.[2] In additional experiments higher saturation pressures were used and the curves relating gas and liquid permeabilities were established.

RESULTS

The relations obtained between permeabilities and saturation for Nichols buff sandstone are shown in Fig. 3. The term "specific permeability" in the ordinate of the curves means the permeability of the medium to a single-phase homogeneous fluid of unit viscosity, and is used throughout this paper for the sake of brevity. For purposes of comparison the corresponding relations obtained for the finest unconsolidated sand used in previous experiments (permeability 17.8 darcies) are shown in the dotted curves. The equilibrium saturation for both the consolidated and the unconsolidated sand is 90 per cent. Above the equilibrium saturation, the curves coincide, and in this region the gas permeability is essentially zero. The fact that the liquid permeability curve for consolidated sand coincides with that for unconsolidated sand down to equilibrium saturation might be interpreted as indicating that the mechanism of the approach to equilibrium saturation is fundamentally the same, regardless of whether or not the sand is consolidated. Furthermore, the initial plugging probably occurs in the larger pores, as indicated by the very large decrease in permeability for a small decrease in saturation. It is probable, from obvious considerations, that the larger pores are relatively less affected by cementation than the smaller ones, hence the process of plugging the larger pores of a consolidated sand with gas bubbles might be expected to correspond closely to the

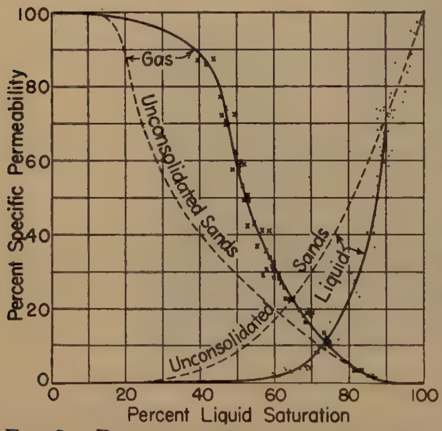

FIG. 3.—PERMEABILITY-SATURATION CURVES.

same process for unconsolidated sands. Some idea of the rapidity of approach to equilibrium saturation may be obtained from Fig. 4. In this figure the fraction of the pores filled with gas is plotted against the total volume of free gas that has passed through the pores, including that which has been retained. The fraction of pores filled with gas rises linearly until approximately 11 per cent is filled with gas, after which additional gas passes through the sand with only negligible increase in plugging action. From this it may be concluded that, even in the case of consolidated sands, the initial gas coming out of solution as a result of pressure decrease is held in the pores until a certain definite fraction is gas filled, after which, if the gas-liquid ratio is maintained at a sufficiently low value, the gas continues to flow through the sand without displacing any additional liquid.

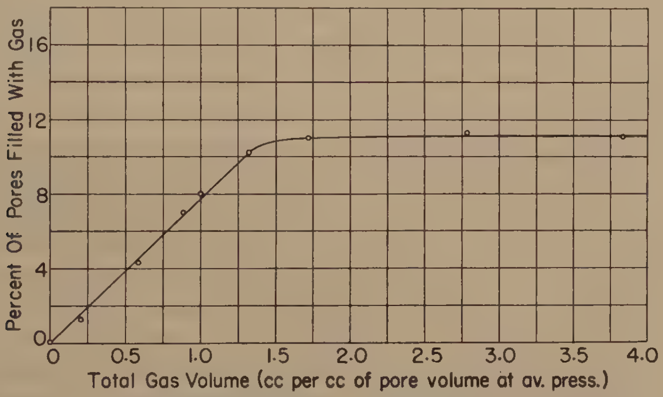

FIG. 4.—RATE OF DEVELOPMENT OF EQUILIBRIUM SATURATION.

The effects of the many possible variations of the factors involved in the flow through consolidated sands make it very difficult to interpret the differences between the curves for consolidated and unconsolidated sands. This difficulty is further increased by the fact that only one consolidated sand has been studied, so that the magnitude of deviations among the various consolidated sands is unknown. It will suffice here to suggest some of the possible interpretations and leave to the future, when more data may be available, the decision as to the best approximation to the real physical phenomena involved.

It will be noted, from Fig. 3, that immediately below 90 per cent saturation the decrease in permeability for unit change in saturation is extremely rapid, a decrease in saturation from 90 to 82 per cent reducing the permeability by 60 per cent. From one viewpoint, this might be regarded as indicating a nonuniform distribution of pore sizes such that at this point a large number of pores, having about the same size, are being filled with gas bubbles and eliminated from the flow system, since, although the liquid permeability decreases greatly, there is comparatively little increase in gas permeability. This is in line with the results obtained in another investigation on Nichols buff sandstone in which the saturation was obtained as a function of the rate of pressure decline.[2] Fig. 6 of the paper describing that investigation shows that between saturations of 82 and 90 per cent there is a very rapid change in saturation with comparatively small change in rate of pressure decline. This was interpreted as indicating that there is a nonuniform distribution of pore sizes and when a gas velocity is developed only slightly greater than that required to obtain equilibrium saturation, a large number of pores of about the same size become filled with gas, rapidly reducing the saturation until most of the pores of that particular size are gas filled. This rapid filling with gas would have a very great effect on the liquid permeability, because the larger pores would fill first and thus, under the comparatively low gradients developed for this region of saturation, the liquid permeability should decrease very greatly over this (82 to 90 per cent) saturation region.

In connection with this hypothesis, an analysis was made of the grain-size distribution of the sandstone. The results are shown graphically in Fig. 5. There is a comparatively large fraction of the grains having the same size (between 80 and 90 mesh). The material through 130 mesh is very fine, so that nearly 15 per cent of the sand may be regarded as cementing material. The fact that the size of grain present in largest proportion is essentially the coarsest of the various grain sizes would tend to confirm the hypothesis that a great many of the larger pores are of nearly the same size, so that a large decrease (60 per cent) in liquid permeability results from a small change in liquid saturation over the saturation interval (90 to 82 per cent), in which these larger sized pores are being filled with gas.

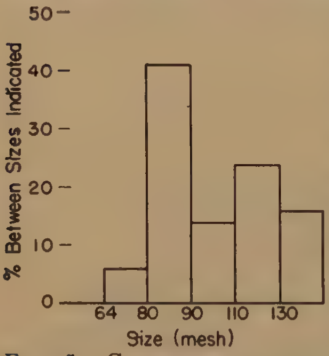

FIG. 5.—GRAIN ANALYSIS OF NICHOLS BUFF SANDSTONE.

From another viewpoint, it will be noted that for liquid saturations between 82 and 90 per cent, the gas-permeability percentage is the same for both unconsolidated and consolidated sands, while the percentage of liquid permeability of the latter is considerably lower. This indicates that the energy loss in forcing the mixture through the sand is greater than for unconsolidated sands, and that this extra energy must be used on the liquid flow, since the gas-permeability curve in this region coincides with that for unconsolidated sands. The cementing material in the consolidated sand tends to round out the pore spaces and the interpore constrictions, therefore a small bubble of gas under a slight pressure gradient might more easily be able to block a given pore outlet completely, preventing any by-passing past the bubble and forcing the liquid to flow through some side opening of the pore, thus greatly lengthening its path and reducing the apparent liquid permeability. In an unconsolidated sand the comparatively very irregular interpore constrictions would tend to reduce the effectiveness of this plugging action to a minimum, and of course the effect would vary greatly with the nature and degree of cementation of a consolidated sand. Doubtless emphasis on other factors would permit the development of other hypotheses as to the physical phenomena involved, but the data so far available are not sufficient to be used as criteria in choosing any one explanation over the others. So further conjecture should await the acquisition of additional data.

Also, in regions of lower liquid saturation the gas-permeability percentage is higher than for the corresponding saturation in the unconsolidated sand. This might be expected from the smoothing out effect of the cementation on the interpore constrictions and on the pore spaces, permitting the gas to flow more easily through the sand, once its flowing mass is large enough to prevent or eliminate the formation of single bubbles in single pores. Consolidated sand contains a much larger proportion of very small pores, which make negligible contribution to the flow. The small pores of the unconsolidated sediments are probably made much smaller by the process of cementation, especially in a sand that contains practically 15 per cent by weight of cementing material. This is a factor, of course, which is very unfavorable to ultimate recovery and indicates that from the standpoint of permeability-saturation relations consolidated sands will, in general, show much lower ultimate recoveries than unconsolidated sands. This is brought out more clearly by comparing gas-liquid ratios. In Fig. 6 are plotted the ratios of gas-liquid permeabilities for the two sands, as read from the curves of Fig. 3. The gas-liquid ratio rises much more rapidly and at a higher liquid saturation for the consolidated sand. It indicates that the recovery from the consolidated sand would be less, even for a practically infinite gas-liquid ratio, than from the unconsolidated sand at a finite ratio.

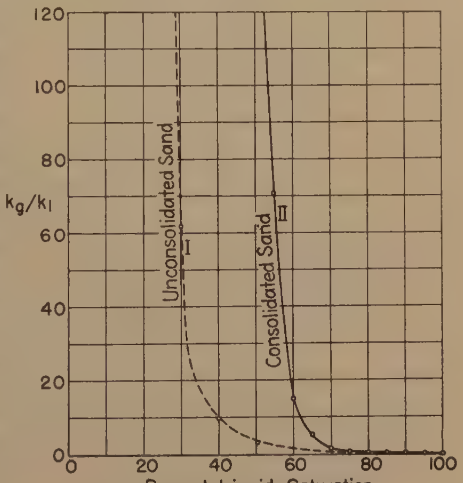

FIG. 6.—GAS-LIQUID RATIOS.

Below a saturation of about 65 per cent, the permeability of the Nichols buff sandstone to liquid is very small, while production experiments on a small Nichols buff core indicated that the recovery curve becomes approximately asymptotic to a saturation of 65 per cent at extremely high gas-liquid ratios.

It must be borne in mind constantly that the magnitude of these variations and differences will depend on the individual consolidated sand in question, and can only be determined in detail by actual experiments on the sand about which information is desired. However, it may be concluded that in general a sand containing a large amount of cementing material is apt to show a proportionally lower recovery than a sand of similar permeability and porosity, but with a small amount of cementation.

In Fig. 7 are plotted the gas-liquid ratios in two sections of the sand column for a single experiment. It appears that for gas-liquid ratios below about 0.8, the saturation of the sandstone remains at its equilibrium value. It will be recalled that unconsolidated sands maintain their equilibrium saturation up to gas-liquid ratios of about 1.5. Apparently wide variations in grain size and cementation reduce slightly the maximum gas-liquid ratio at which equilibrium conditions can be maintained. This indicates that the forces involved in forming and displacing the tiny gas bubbles are of the same order of magnitude in both types of sand. The slightly lower maximum gas-liquid ratio for equilibrium conditions in consolidated sand is to be expected, since the effect of cementation is, in general, to eliminate rough edges and sharp angles and to smooth the capillary passages through the sand.

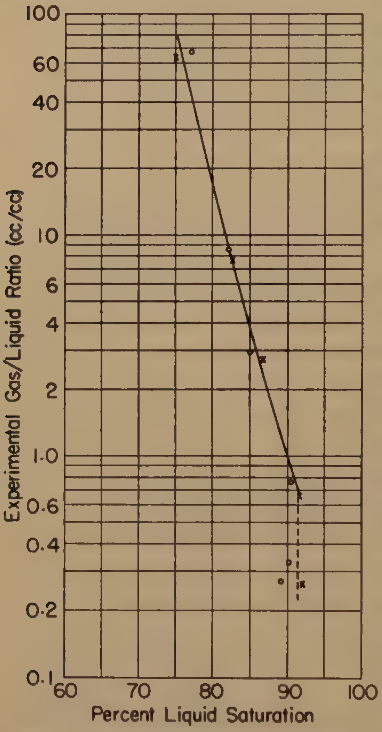

Fig. 7.—Gas-liquid ratio versus saturation.

Pressure Decline

Having a core of such comparatively large dimensions available, it next seemed desirable to make some experimental studies of production-decline phenomena. To do this the core was filled with gas-saturated liquid, the inlet valve closed and the outlet valve opened to atmospheric pressure. The rates of liquid and gas production were measured, as well as the saturation distribution and pressure distribution along the core. These measurements were made at brief intervals until the production from the sand ceased. The pressure distributions at different intervals during the experiment are plotted in Fig. 8. These curves are in general agreement with similar pressure-decline curves calculated for linear flow in unconsolidated sand,[5] and are in general agreement with similar curves obtained by Reid and Huntington[6] for high-pressure experiments on crude and natural gas. The first pressure curve (6 per cent production) shows a lower outlet pressure than the subsequent curves, which doubtless is because very little free gas had had time to form in the outlet when the data for this curve were taken. After an appreciable amount of gas had begun to flow, a slight back pressure was built up in the outlet valve and tubing, thus raising the pressure slightly at the outlet face of the sandstone.

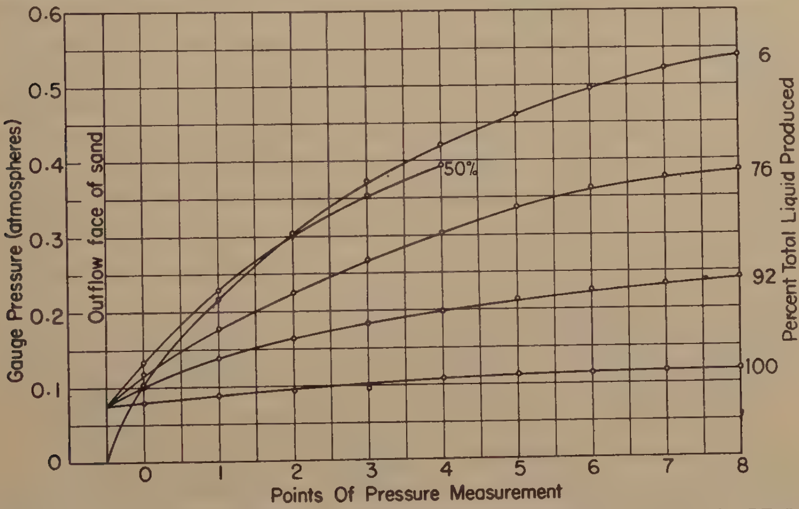

FIG. 8.—PRESSURE DISTRIBUTION ALONG SAND COLUMN DURING PRODUCTION DECLINE.

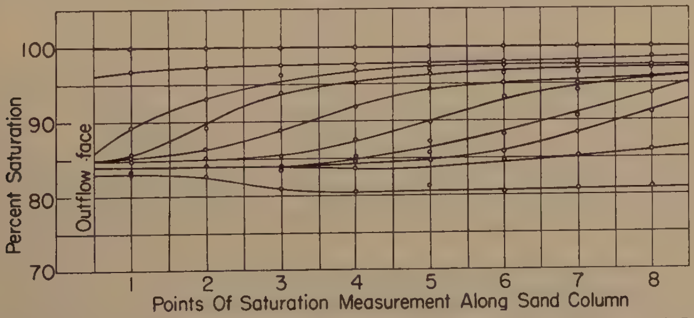

FIG. 9.—SATURATION DISTRIBUTION ALONG SAND DURING PRODUCTION DECLINE.

In Fig. 9 are plotted the saturation distributions along the sandstone for successive stages of pressure decline. These curves show a rather unexpected variation of saturation distribution with production, in that the progressing saturation curve exhibits an inflection, which begins at the outflow end of the sand and gradually passes along the column to the inlet end. The curve of final saturation also indicates that at the time of depletion there is higher saturation near the outlet of the sand than at the inlet. This appeared to be physically unreasonable and additional experiments were performed to check the reality of these phenomena. It was thought that possibly the manometers, which contained a certain amount of liquid, might, as the fluid levels in them varied with progressive depletion, make some contribution to the saturation distribution and hence might possibly be responsible for the observed saturation phenomenon. To test this, the manometers were completely disconnected from the flow column and no pressure measurements were made. In addition, the end of the sand that had been the inlet during the process of filling with saturated liquid was made the outlet for the production-decline experiment. As in the preceding experiment, the outlet valve was opened wide and the pressure allowed to decline at its maximum rate. The saturation distribution at various stages of decline is plotted in Fig. 10. It is apparent at once that the saturation variation is almost identical with that of Fig. 9, except for ultimate distribution, and may therefore be regarded as real. It may be further concluded from the data of this experiment that the saturation along the sand column at ultimate depletion is uniform, the variation being less than 1 per cent.

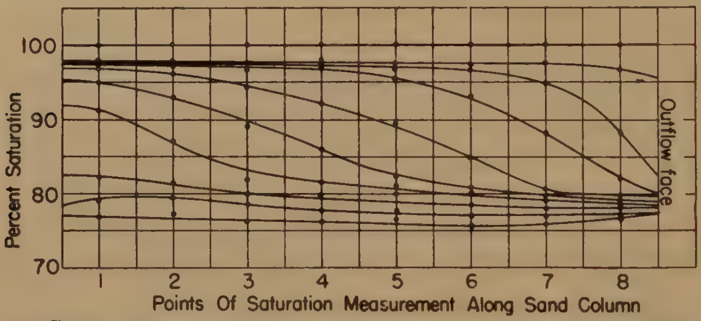

FIG. 10.—SATURATION DISTRIBUTION ALONG SAND DURING PRODUCTION DECLINE.

Several pressure-decline experiments were performed at various saturation pressures (Table 1). The agreement between the final saturation, determined from the electrical resistance, and that obtained from the measurement of the liquid produced, is fairly good. This agreement would probably have been even better had the free volume in the system (volume not occupied by sand) been known more accurately. This amounted to somewhere between 60 and 90 c.c. A blanket correction of 75 c.c. has been applied in calculating the production for all the experiments. It is probable that for various rates of pressure decline, various amounts of liquid were produced from the free volume of the system, thus, for highest accuracy, requiring a separate correction for each experiment. Consequently, it is thought the resistance measurements provide a more accurate knowledge of the actual volume of liquid produced from the sand itself and so the calculations of production have been made from the resistance measurements.

TABLE 1.—*Pressure-decline Experiments*

Absolute Saturation Pressure, Atmospheres	$\frac{p_i}{p_f}$	Final Average Saturation		Percentage of Total Liquid Produced, from Electrical Resistance
		From Liquid Produced	From Electrical Resistance	
1.640	1.66	0.824	0.814	18.6
1.928	1.95	0.790	0.801	19.9
2.018	2.05	0.801	0.778	22.2
2.148	2.18	0.784	0.762	23.8
3.898	3.97	0.753	0.758	24.2
5.528	5.65	0.747	0.742	25.8

In all these experiments the pressure was allowed to decline at its maximum rate. The relation between saturation pressure and liquid production is plotted in Fig. 11. It is apparent that above a saturation pressure of about 2.5 atm. abs. the volume of liquid produced is essentially independent of the saturation pressure. This is in accord with the pressure-reduction experiments on the small cores of Nichols buff sandstone,[2] wherein it was found that variations in saturation pressures up to 900 lb. per sq. in. had negligible effect upon the final saturation of the core, which was about 76 per cent. The final saturation in the pressure-decline experiments of Fig. 11 was about 75 per cent, for saturation pressures above 2.5 atm. This agreement between the two cores of this sandstone of such widely different size and involving quite different fluids shows the relative unimportance of such fluid properties as surface and interfacial tension and viscosity, as well as saturation pressure, and indicates that one may, with some degree of confidence, extrapolate results

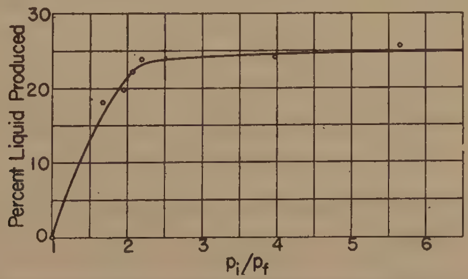

FIG. 11.—RELATION BETWEEN SATURATION PRESSURE AND LIQUID PRODUCTION. p_i/p_f = ratio of saturation pressure to final pressure.

from small core samples to field applications. These results also indicate that, for producing fields, the maximum production obtainable by ordinary primary recovery methods, neglecting such factors as structure and water drive, is essentially independent of the saturation pressure and may be determined by simple laboratory experiments on field cores. Increases or decreases of recovery over or under this value may then be regarded as the result of structure, operating technique, presence and distribution of connate water, water drive, and other factors.

The decline in liquid flux from a linear channel originally filled with saturated liquid has been calculated for unconsolidated sand.[5] The experimentally determined decline in liquid flux for the consolidated sand is plotted in Fig. 12; it is essentially the same curve as that calculated for unconsolidated sands.

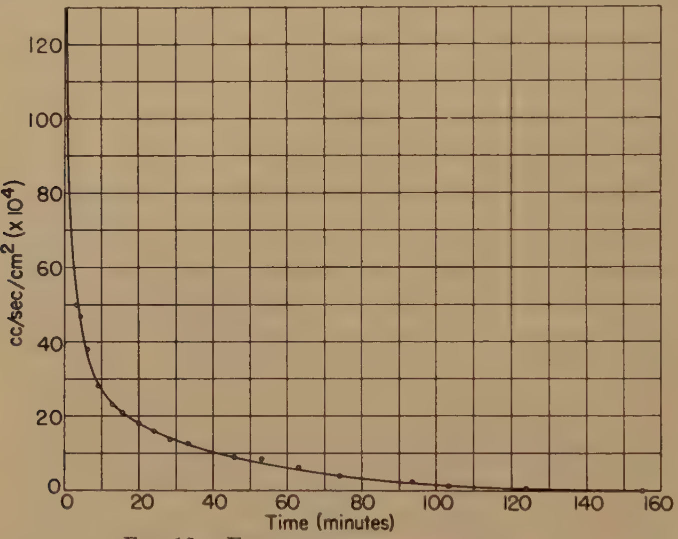

FIG. 12.—EXPERIMENTAL DECLINE CURVE.

CONCLUSIONS

The following conclusions may be drawn from the experiments on consolidated sand:

1. The mechanism of approach to equilibrium saturation is very little affected by the consolidation of the sand.

2. The equilibrium saturation is probably dependent upon the cementation and grain-size distribution, but it may easily be determined on a small core sample.

3. The cementation and the grain-size distribution of the sand are also important in their influence on the permeability-saturation relation. For quantitatively applicable results these relations should be determined on the actual sand in question. The experiments reported herein on

Nichols buff sandstone have served to point out certain general trends and tendencies and to enable us to obtain a broad general picture of the significance of cementation and grain-size distribution in modifying the permeability-saturation relations of unconsolidated sand.

4. The ultimate recovery from a consolidated sand will in general be less than that from an unconsolidated sand of the same permeability, the difference in recovery depending upon the grain-size distribution and the degree of cementation.

5. Assuming a uniform sand with no water drive or structure present, the final saturation, at the conclusion of the period of natural production, is essentially uniform throughout the sand body.

6. Surface and interfacial tension as well as viscosity must be relatively unimportant (at least over a moderate range of variation) since results of experiments on the large core with water and carbon dioxide agree with those obtained on a small core with natural gas and oil.

The experiments described above have sufficed to show the nature and magnitude of deviations from the permeability-saturation relations for unconsolidated sands, to be expected as a result of consolidation. Furthermore, they indicate that the methods of analysis developed and general conclusions drawn for unconsolidated sands[4,5] will, with suitable minor adjustments dependent upon the characteristics of the particular sand in question, be equally applicable to consolidated sands. Since these minor adjustments are dependent upon the nature of the individual sand, any attempt to evaluate in detail the effects of such features as degree of cementation or grain-size distribution will involve an extensive program of experiments on a number of different sandstones. Such experiments should produce results of value to the petroleum industry and it is to be hoped that some organization will find it possible to perform them.

Acknowledgments

The author wishes to express his appreciation of the many helpful discussions with Dr. M. Muskat during the course of these experiments, and to thank Dr. Paul D. Foote, Executive Vice President of the Gulf Research and Development Co., for permission to publish these results.

References

1. H. G. Botset: *Rev. Sci. Instr.* (1931) **2**, 84.
2. H. G. Botset and M. Muskat: *Trans.* A.I.M.E. (1939) **132**, 172.
3. M. C. Leverett: *Trans.* A.I.M.E. (1939) **132**, 149.
4. M. Muskat, R. D. Wyckoff, H. G. Botset and M. W. Meres: *Trans.* A.I.M.E. (1937) **123**, 69.
5. M. Muskat and M. W. Meres: *Physics* (1936) **7**, 346.
6. L. S. Reid and R. L. Huntington: *Trans.* A.I.M.E. (1938) **127**, 226.
7. R. D. Wyckoff and H. G. Botset: *Physics* (1936) **7**, 325.

DISCUSSION

(M. T. Halbouty presiding)

M. C. LEVERETT,* Houston, Tex.—Particular interest attaches to the curves of Figs. 9 and 10 and Mr. Botset's remarks regarding them. Work under way for some time in this laboratory shows the existence of valid theoretical reasons for expecting the liquid (or wetting) phase to accumulate behind the outflow face of the sand in production experiments like those described by Mr. Botset. The curves of Figs. 9 and 10 show clearly that this occurred during the flow of liquid and gas from the consolidated core. This behavior has been repeatedly observed with unconsolidated sands in this laboratory. Its origin lies in the existence of capillary forces in the sand that cause the sand to imbibe the wetting phase from regions contiguous to the sand in which the capillary pressure is less than in the sand. This "boundary effect," as it may be termed, may be expected at any discontinuity or change of texture in the sand.

S. E. BUCKLEY,† Houston, Tex.—It is not my intention to comment upon the specific data presented in this paper other than to remark that these additional results completely verify the relations developed in previous investigations by the same author and his collaborators. My purpose is rather to call attention to the broader implications and the fundamental importance of the principles involved in the flow of oil and gas through sands as set forth in the relations discovered in these investigations. Regardless of the geometrical complexity of the conditions met in actual practice and the resulting difficulty in drawing exact quantitative conclusions, the underlying physical principles may be discovered through laboratory investigation, and once delineated and understood may be relied upon for the interpretation of the behavior of individual wells and of complete reservoirs. In fact, a knowledge of these principles is absolutely essential to any intelligent study of the drainage of oil and gas, the spacing of wells, the value of gas injection, or the use of water-flooding in secondary recovery operations.

Of particular importance at this time is the application of the relations developed by these investigators to the problem of well spacing. The most significant single result is the experimental demonstration that in a sand containing gas and oil there exists no combination of fluid saturations at which flow is stopped by bubble interference or "Jamin effect," while there still exists a finite pressure gradient in the sand. Thus, the analogy to flow through a single continuous capillary, in which flow may be stopped by alternate bubbles of gas and oil in spite of an applied pressure gradient, is destroyed. As a result of the continuously interlocking passages in a sand, the physical nature is quite distinct from that presented by a bundle of single nonconnecting capillaries and the flow relations are correspondingly different. It follows that so long as a pressure gradient exists in a continuous body of sand flow will continue. There is thus no theoretically fixed finite limit of drainage to a well other than that imposed by the physical boundaries of the sand body penetrated. With this principle once fully understood and appreciated, it should become possible to treat the problem of well spacing on a sound basis with proper attention to the different physical and economic factors involved in any individual case.

H. E. POTTER,‡ Tyler, Tex.—On salt-water injection projects for disposal purposes reinjection pressures, after injection has been interrupted, are often considerably higher than normal operating pressures. The particular instance I have in mind is an injection in the East Texas field. On this well there is about 100 ft. of open sand into which the water is being injected. This sand is porous and permeable. The water that we attempted to inject was treated to remove all solid material and all possible precipitates, so that there would be no substances clogging the sand face. When injection was started the well took water under vacuum at the well head. However, in a short time injection could not be continued by gravity and it was necessary to force the water into the sand by pump pressure. This was not too successful, and, in order to open a channel and increase permeability, high-pressure pumps were used, and the injection rate was increased to 200 bbl. per hour. At this rate the pressure increased to a maximum of 1800 lb. per sq. in., and as injection continued at the same volume the pressure dropped to 350 lb. per sq. in. The high-pressure pumps were then removed and the water was injected under vacuum for a few days, but the volume gradually fell off until it was again necessary to use pump pressure. The erratic behavior of the well may have been due to intermittent injection, as the well was shut in each night and started the next day. However, this intermittent injection resulted in definite changes in the ability of the sand to take water, which from our present knowledge of permeability is hard to explain. All this goes to show that the permeability of a sand may change when liquids are passed through it in the same manner as when gas is passed through the sand. Further work along this same line as outlined in this paper should result in obtaining much valuable data regarding such changes in permeability.

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A. G. LOOMIS,* Emeryville, Calif.—In connection with Mr. Botset's work on the flow of gas-water mixtures through cores, I would like to mention the earlier work of Dr. Gerald Hassler[8] on the flow of gas-oil mixtures. The experiments of Hassler were the first quantitative studies of the flow of mixtures through consolidated cores, so far as I am aware. His experiments have the distinct advantage that they were made with Bradford oil-field cores and in view of the fact that the wetting characteristics and the degree of cementation of the sand play a dominant role in the flow of polyphase systems, it would be interesting to compare Hassler's results with those obtained by Botset with an outcrop rock and with gas-water mixtures.

H. G. BOTSET (author's reply).—The author is aware of the paper by Hassler, Rice and Leeman, referred to by Dr. Loomis. The experiments of these authors were of a different type, however, since they were concerned merely with secondary recovery by gas drive, and, as stated by the authors, the experiments involve only the flow of dead oil driven by gas through very small cores (1 in. long) at pressure gradients of 40 lb. per sq. in. The conditions of the experiments were such as to bear little relation to the actual conditions found in practice. In such small cores, the boundary effects mentioned by Dr. Leverett would undoubtedly be of considerable importance. In view of the fact that in the work of Hassler, Rice and Leeman the experimental technique was so utterly different, that a dead oil was used instead of a gas-saturated liquid, and that in no case was a steady-state condition attained, it seems unnecessary to compare the two papers.

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* Shell Development Co.

[8] G. L. Hassler, R. R. Rice and E. H. Leeman: Investigations on the Recovery of Oil from Sandstones by Gas Drive. *Trans.* A.I.M.E. (1936) **118,** 116.

Phase Diagram of a Mixture of Natural Gas and Natural Gasoline Near the Critical Conditions

By D. L. Katz,* Member A.I.M.E., D. J. Vink† and R. A. David†

(Galveston Meeting, October 1939)

A phase diagram showing boundary curve and quantity of liquid in the two-phase region was determined for a mixture of natural gas and natural gasoline in the region of its critical conditions. The temperatures and pressures of phase measurements were in the range of 85° to 212° F. and 1300 to 2600 lb. per sq. in., respectively, with the critical conditions at 169.5° F. and 2615 lb. per sq. in. abs. Color phenomena were observed in the region of the boundary curve from 102° to 192° F. Approximate densities of the single-phase and two-phase regions and analysis of the system are included.

Boundary curves between the single-phase and the two-phase regions have been determined for several binary mixtures containing hydrocarbons.[2,3,4,6,7,10,11,12,14] These investigators did not report the relative amounts of liquid and vapor within the two-phase region. The equilibrium values obtained from the dew-point and bubble-point data can be used to compute the lines showing percentage of liquid on the pressure-temperature phase diagram[8] but the positions of the lines near the critical temperature and pressure are uncertain. Relative amounts of vapor and liquid were obtained for a gasoline and a naphtha[1] within the two-phase area but not in the region of the critical temperature and pressure. The bubble-point and dew-point lines, as well as the percentage liquid lines within the two-phase region, were determined by visual observations in glass apparatus.

Apparatus

An arrangement of the apparatus is given in Fig. 1, showing the Jerguson gauge *A* with glass windows *B*. Pressure was supplied by the

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[2] References are at the end of the paper.

mercury pump *C* and measured by a calibrated Bourdon gauge *D*. Agitation to insure equilibrium was obtained by rocking the entire gauge assembly around axis *E-F*. A constant-temperature air bath permitted control of the temperature of the gauge. The scale beside the glass window was used to calibrate the volume of the gauge by mercury displacement. This scale was used to measure the position of the gas-liquid meniscus, if present, and to measure the hydrocarbon-mercury meniscus.

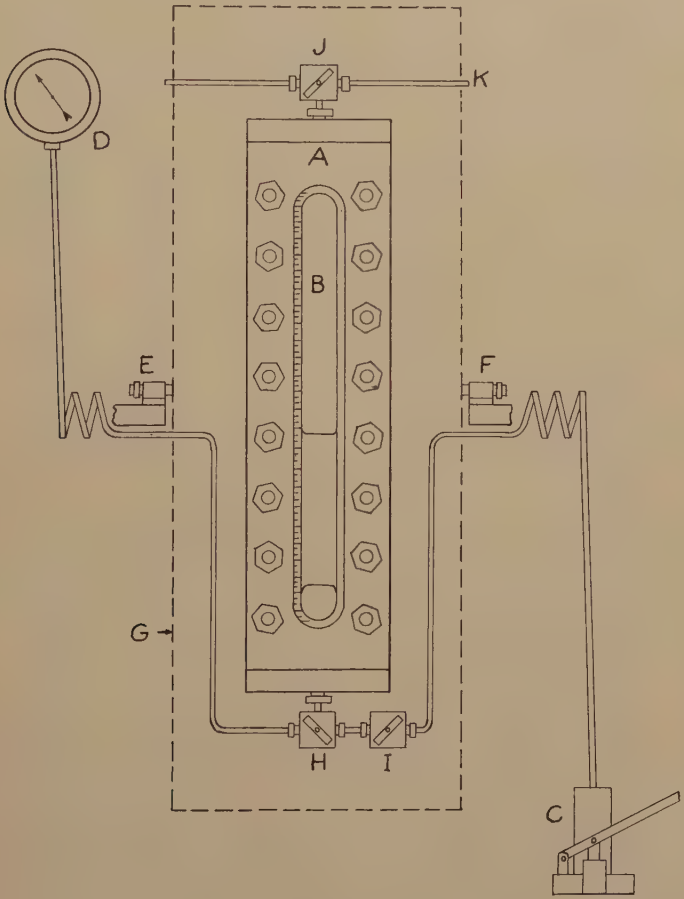

FIG. 1.—ARRANGEMENT OF APPARATUS.

A, Jerguson gauge
B, glass window.
C, mercury pump.
D, Bourdon gauge.
E-F, axis.
G, air bath
H, valve.
I, valve.
J, valve.
K, charge line.

Volume Measurements

The entire system was filled with mercury, to remove air, then natural gasoline was drawn into the gauge through line *K*, by allowing the

TABLE 1.—*Liquid Percentage as a Function of Pressure and Temperature*

Pressure, Lb. per Sq. In. Abs.	Total Volume, C.C.	Liquid Volume, C.C.	Percentage Liquid by Volume	Pressure, Lb. per Sq. In. Abs.	Total Volume, C.C.	Liquid Volume, C.C.	Percentage Liquid by Volume
Temperature 85° F.				Temperature 102° F.			
2,500	51.6	Single phase		2,585	53.0[a]	Single phase	
2,483	52.0	49.5	95.2	2,575	53.2	Single phase	
2,425	53.2	42.7	80.2	2,568	53.2	Single phase	
2,317	55.7	37.1	66.6	2,567	53.2	52.6[a]	98.9
2,175	59.7	33.3	55.7	2,557	53.4	51.3	96.0
1,935	68.0	29.6	43.5	2,547	53.9	48.9	90.7
1,591	85.8	27.3	31.8	2,525	54.2	44.3	81.5
1,475	93.5	26.4	28.2	2,505	54.9	41.4	75.3
1,325	105.6	24.2	22.9	2,580	55.2	38.7	70.1
1,248	113.7	23.5	20.7	2,450	56.1	37.0	65.9
1,160	124.0	22.9	18.5	2,410	57.3	35.4	61.6
1,085	132.6	21.9	16.5	2,350	58.9	33.2	56.4
1,040	139.1	21.9	15.7				
Temperature 119° F.				Temperature 145° F.			
2,605	56.1	Single phase		2,613	60.0	Single phase	
2,583	56.4	51.8	91.7	2,607	60.0	Single phase	
2,570	56.7	48.7	85.9	2,603	60.1	56.2	93.6
2,558	56.9	46.7	82.1	2,596	60.9	49.0	80.4
2,535	57.6	42.9	74.5	2,590	60.9	47.6	78.2
2,501	58.1	39.6	68.1	2,575	61.2	41.6	68.0
2,537	60.0	36.2	60.3	2,537	62.3	36.8	59.1
2,359	62.1	33.4	53.8	2,400	66.3	31.7	47.9
2,272	64.6	31.6	48.8				
2,160	68.6	30.1	43.9				
Temperature 151° F.				Temperature 166° F.			
2,609	60.9	Single phase		2,615	64.0	Single phase	
2,605	60.9	Single phase		2,610	64.2	35.5	55.2
2,600	61.0	56.7	93.0	2,600	64.3	32.8	51.0
2,597	61.2	51.3	83.8	2,585	64.7	31.8	49.1
2,583	61.8	42.9	69.4	2,515	67.9	30.8	45.4
2,560	62.1	37.6	60.5	2,183	78.2	26.0	33.2
2,495	64.2	33.6	52.3	2,000	86.6	25.0	28.9
2,390	67.5	31.0	45.9	1,875	93.1	24.0	25.8
				1,740	101.1	22.1	21.8
				1,595	111.6	21.3	19.1
				1,460	122.9	20.0	16.3
				1,345	134.6	19.2	14.3

---

[a] Experimental volumes × 0.86 since this run was taken with larger amount of material in system. After this run some of the uniform phase was vented off to give a workable volume for system.

mercury to gravitate to the pump with valves *H* and *I* open. Natural gas was metered in another glass-windowed gauge at 645 lb. per sq. in. abs. and then injected into line *K* with the removal of the mercury level

TABLE 1.—(*Continued*)

Pressure, Lb. per Sq. In. Abs.	Total Volume, C.C.	Liquid Volume, C.C.	Percentage Liquid by Volume	Pressure, Lb. per Sq. In. Abs.	Total Volume, C.C.	Liquid Volume, C.C.	Percentage Liquid by Volume
Temperature 169° F.				Temperature 171° F.			
2,615	64.2	Single phase		2,615	65.6	Single phase	
2,614	64.3	32.0	49.8	2,605	65.6	Single phase	
2,606	64.5	31.3	48.5	2,603	65.7	Single phase	
2,599	65.1	31.0	47.6	2,595	65.8	26.9	40.9
2,585	65.2	30.5	46.7	2,582	66.1	27.9	42.2
2,560	65.9	29.6	44.9	2,570	66.3	28.1	42.4
2,510	67.3	28.9	42.9	2,548	66.9	28.1	42.0
2,167	80.0	25.9	32.4	2,503	68.4	27.9	40.8
1,960	89.7	24.5	227.3	2,235	78.0	26.0	33.4
1,760	100.8	22.0	21.8	2,093	84.2	25.1	29.8
1,390	132.2	20.3	15.4	1,942	91.7	24.4	26.6
				1,773	101.8	22.7	22.3
				1,680	108.0	21.7	20.1
				1,590	114.7	21.0	18.3
				1,495	122.9	20.4	16.6
				1,410	130.8	19.4	14.8
				1,328	140.3	19.4	13.8
Temperature 181° F.				Temperature 181° F. (*Continued*)			
2,615	67.2	Single phase		2,530	69.8	26.5	38.0
2,610	67.2	Single phase		2,285	78.4	25.3	32.3
2,605	67.3	Single phase		2,163	83.6	25.0	29.9
2,600	67.7	14.5	21.4	2,020	90.3	24.1	26.7
2,592	67.7	22.1	32.6	1,825	101.1	22.0	21.8
2,583	68.0	24.0	35.3	1,688	110.6	21.2	19.2
2,569	68.3	25.3	37.0	1,565	119.6	19.9	16.7
2,559	68.8	25.8	37.5	1,363	139.5	18.5	13.3
Temperature 192° F.				Temperature 212° F.			
2,623	69.3	Single phase		2,535	76.4	Single phase	
2,590	69.4	Single phase		2,525	76.5	6.1	8.0
2,579	69.7	5.9	8.5	2,512	77.0	6.9	9.0
2,575	69.8	10.4	14.9	2,475	78.4	10.4	13.3
2,560	70.4	15.7	22.3	2,425	80.0	14.1	17.6
2,540	70.8	18.4	26.0	2,410	80.8	14.9	18.5
2,510	71.7	20.4	28.5	2,350	83.0	16.6	20.0
2,460	73.5	21.8	29.7	2,270	86.4	17.6	20.4
2,395	76.2	22.4	29.4	2,077	95.4	17.6	18.5
2,333	78.7	22.8	29.0	1,935	103.3	16.8	16.3
2,173	85.5	22.3	26.1	1,810	111.2	16.4	14.8
1,888	100.1	20.3	20.3	1,740	116.4	15.8	13.6
1,693	113.3	18.8	16.6	1,645	124.3	15.5	12.5
1,561	123.8	17.9	14.5	1,535	133.2	14.0	10.5

to the bottom of the gauge. Gas was added until a brown color appeared at the interface between the vapor and liquid regions, indicating that the critical conditions were likely to be within the temperature and pressure range of the apparatus. Valve *J* was then closed and all volume changes of the system were made by raising or lowering the mercury level in the gauge.

Previous experiments had shown that the best procedure to obtain the phase diagram was to drop the pressure isothermally from the single-phase region to within the two-phase area.

After each pressure change on the system, the apparatus was rocked to thoroughly agitate the system, insuring equilibrium before volume or pressure readings were taken. The first measurements at 85° F. were considerably below the critical temperature, and so pressure drops in the single-phase region obtainable by withdrawing small quantities of mercury showed the meniscus to appear near the top of the gauge and appear at lower positions with subsequent pressure drops. Following each pressure drop, the measurements of pressure and positions of menisci were recorded after agitation. These data and the calibration curve of the volume of the gauge gave the data for Table 1.

A series of experiments at constant temperatures from 85° to 212° F. was made. The data are tabulated in Table 1 and the percentage liquid values are plotted as a function of pressure for each isotherm in Fig. 2. The pressure drop required to change the system from a uniform phase to a definite percentage liquid became smaller as the temperature was raised above 85° F. (Fig. 2). At 169° F., a pressure drop estimated to be one pound caused the single phase to change to a 50.2 per cent vapor and 49.8 per cent liquid system. At temperatures above 169° F. the meniscus between vapor and liquid appeared near the bottom of the gauge for the first pressure drops, rose with pressure reduction for a small pressure drop, and then receded with larger pressure drops.

Phase Diagram

The data of Fig. 2 are cross-plotted on the usual coordinates of pressure and temperature with lines of constant liquid quantity as shown in Fig. 3. The phase diagram is qualitatively similar to what might be expected from known properties of hydrocarbon mixtures.[5,9] The volumetric capacity of the apparatus was not sufficient to reach the lower dew-point curve and the temperatures attainable were below the maximum temperature at which two phases may exist.

The critical conditions of the system are shown to be close to 169° F. and 2615 lb. per sq. in. abs., the point of intersection of the percentage of liquid. The 169° F. points are not evident on Fig. 3 because they practically coincide with the boundary curve. A study of the behavior of the 166°, 169°, and 171° F. isotherms near the uniform phase region of

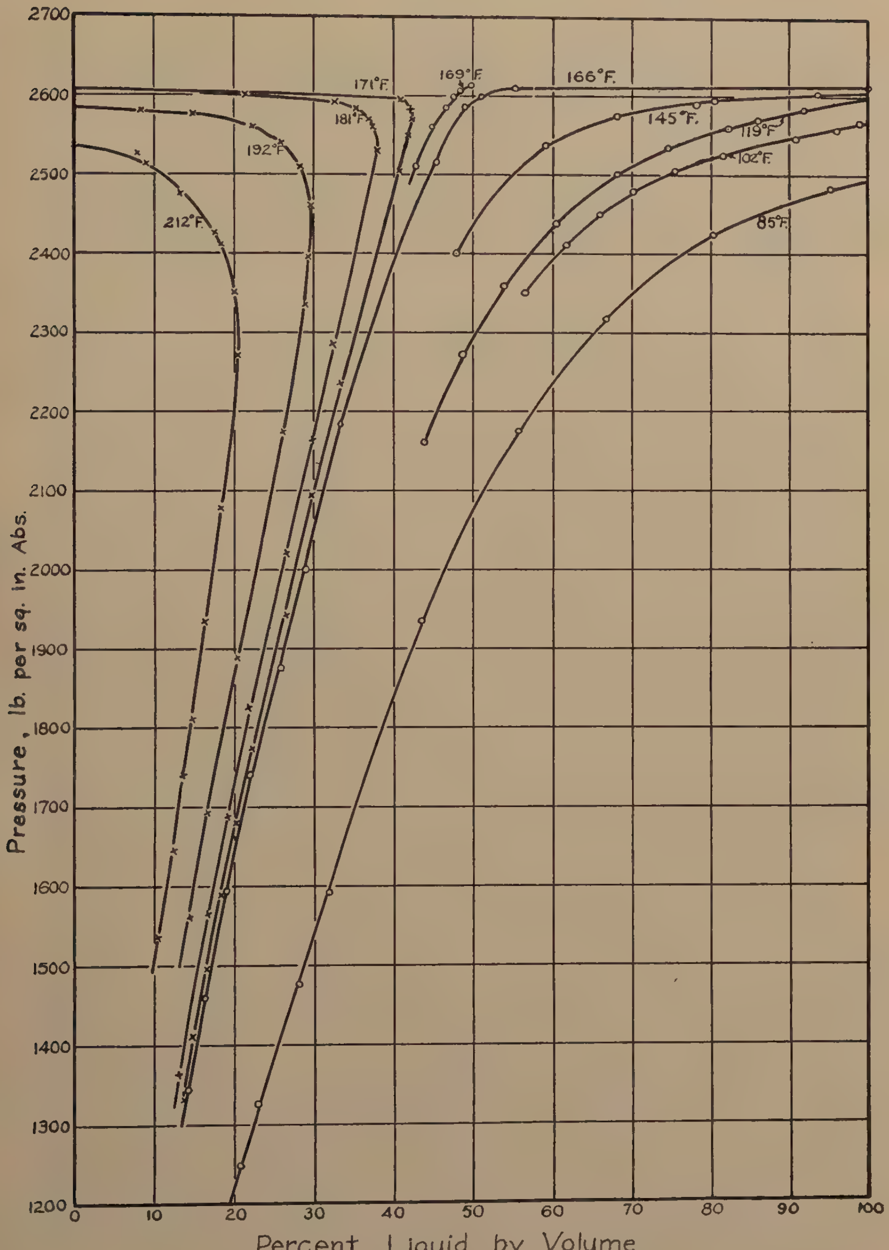

FIG. 2.—LIQUID PERCENTAGE ISOTHERMS.

Fig. 2 indicates that the critical temperature is likely to be about 0.5° F. above the 169° F. Visual observations of the behavior indicate that a temperature can be found at which the meniscus will appear in the middle of the system with an infinitely small pressure drop. This point would then be the exact critical condition, as this condition is boundary to both that of the bubble-point phenomena, where small pressure drops cause the meniscus to appear at the top of the container, and the dew phenomena, where small pressure drops cause the meniscus to appear at the bottom of the container. After agitation adjacent to the critical conditions the entire system was a reddish brown foam. Upon completion of agitation, simultaneous separation of the foam into a uniform but colored phase occurred at the bottom and at the top of the hydrocarbon system. The menisci between the clear phases and the foam traveled from the top and from the bottom toward the middle of the gauge. As the middle was reached, the foam disappeared and a faint meniscus appeared at midposition, showing the upper phase to be gas and the lower to be liquid.

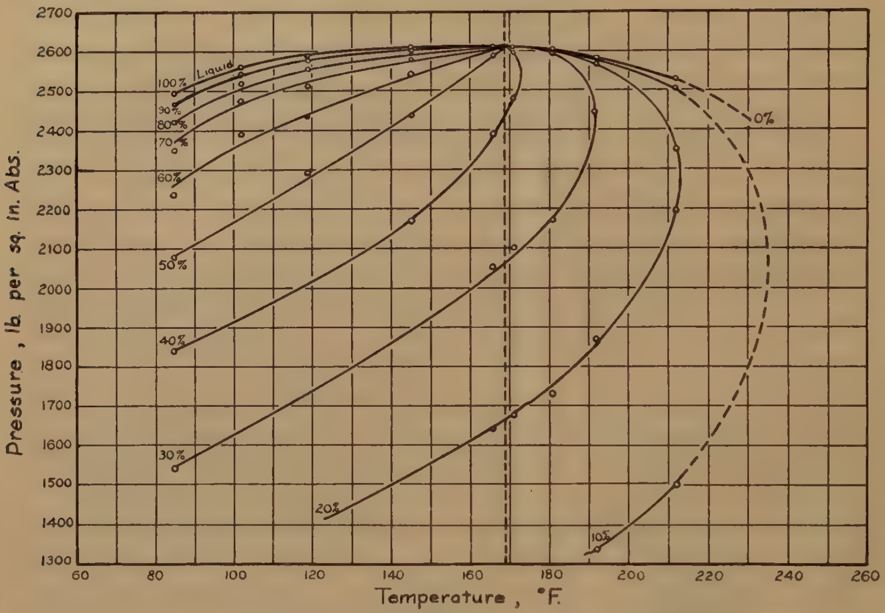

FIG. 3.—PHASE DIAGRAM OF MIXTURE OF NATURAL GAS AND NATURAL GASOLINE. Percentages indicate liquid in system.

The spacing of the 100, 90, 80, and 70 per cent liquid lines of Fig. 3 at temperatures as far as 60° F. from the critical temperature is at smaller pressure intervals than might have been expected, although computations using carefully predicted equilibrium constants had indicated this condition. The nature of the quality lines in the isothermal retrograde condensation area above the critical temperatures are as expected. Fig. 3 shows that a dew-point vapor at 178° F. and 2605 lb. will yield 40 per cent by volume of liquid phase by retrograde condensation when dropping the pressure to 2540 lb. at 173° F. Pressure drops on the system in this region often showed condensation of portions of the vapor and boiling of the liquid to occur simultaneously. The composition of the phases could change with no net change in the volumetric proportion of the liquid phase.

It should be noted that no isobaric retrograde phenomena can occur with the mixture chosen.

Color Phenomena

The striking color phenomena[13] accompanying the measurements near the critical temperature are worthy of note. At pressures considerably above the two-phase region the system was colorless. As the pressure was lowered toward the bubble point or dew point, the single phase took on a reddish color. At temperatures near the critical this color was a bright mahogany red but a faint color effect was perceived in the entire range from 102° to 192° F. The pressure range over which the color persisted on these isotherms was about 20 to 25 lb. The single phase grew in color over a range of about 5 to 10 lb. above the phase boundary and reached its greatest depth just prior to the formation of two phases. The color persisted in both phases in the two-phase region with pressure drops below the boundary as great as 15 lb., although a large reduction in depth of color occurred as this region was entered. A gradual increase in maximum intensity of color occurred as the isotherms approached the critical temperature. There was no evidence that the color described would disappear with added agitation or during the time intervals between experimental observations.

Densities

The information given above was all that was initially expected from the measurements but it was considered worth while to plot the volumes of the system. Fig. 4 gives pressure-volume data for the two-phase system. As little attempt was made to measure the volume of the system in the single phase, the break between the two-phase region and the single-phase region is difficult to obtain unless the pressures were used at 100 per cent liquid or vapor as given in Fig. 2. These two sources permit computation of the volumes of the system at the single-phase boundary.

A measured volume of the single phase was analyzed by fractional distillation, obtaining the composition given in Table 2. The summation of the weights of the hydrocarbons and the volume of the sample at 2500 lb. and 85° F. gave an approximate density of 0.35 grams per cubic centimeter. The fractionating-column operation was not entirely satis-

TABLE 2.—*Analyses of Systems*

Compound	System Having Phase Diagram of Fig. 3, Mol Fraction	System Having $T_c = 72°$ F., $P_c = 2520$ Lb., Mol Fraction
Methane	0.597	.732
Ethane	0.089	.081
Propane	0.050	.027
Butanes	0.049	.026
Pentanes	0.093	.060
Hexanes and heavier[a]	0.122	.074

[a] The distillation range not determined but may be estimated from the A.S.T.M. of the gasoline used, 80° A.P.I., as follows:

Percentage Evaporated	Deg. F.	Percentage Evaporated	Deg. F.
I. B. P.	96	60	152
10	107	70	168
20	112	80	189
30	119	90	224
40	127	E. P.	309
50	137	Residue, 1.8 per cent	

factory, and so the analysis and density are not completely reliable. However, the weight of hydrocarbons in the system while the pressure-volume data were being taken was computed as 18.1 grams based on this density. Also, the densities of the system at the single-phase boundary were computed and are plotted as a function of saturation temperature in Fig. 5.

Two points are significant in these data. First, no unusual change is observed in the shape of the pressure-volume curves for the two-phase system as one passes from temperatures below the critical temperature to the region of retrograde condensation. Secondly, the plot of saturated density appears to be a smooth curve for the bubble-point liquid below the critical temperature and for the dew-point vapor above the critical temperature.

MISCELLANEOUS OBSERVATIONS

Preliminary to the above experiments, considerable work was done on asphalt solubility in volatile hydrocarbon solutions. Also, another system was taken to the critical temperature by changing its composition instead of the temperature. The analysis of this critical mixture is given in Table 2 for a mixture having a critical temperature of 72° F. and a critical pressure of 2520 lb. per sq. in. abs. The natural gasoline was the same for both systems reported, but the natural gases, from a

Gulf Coast well, differed in the pressure and temperature at which they were separated from a liquid.

The experiments using the 24.4° A.P.I. crude oil,[8] propane, and natural gas in the glass-windowed gauge showed two significant results.

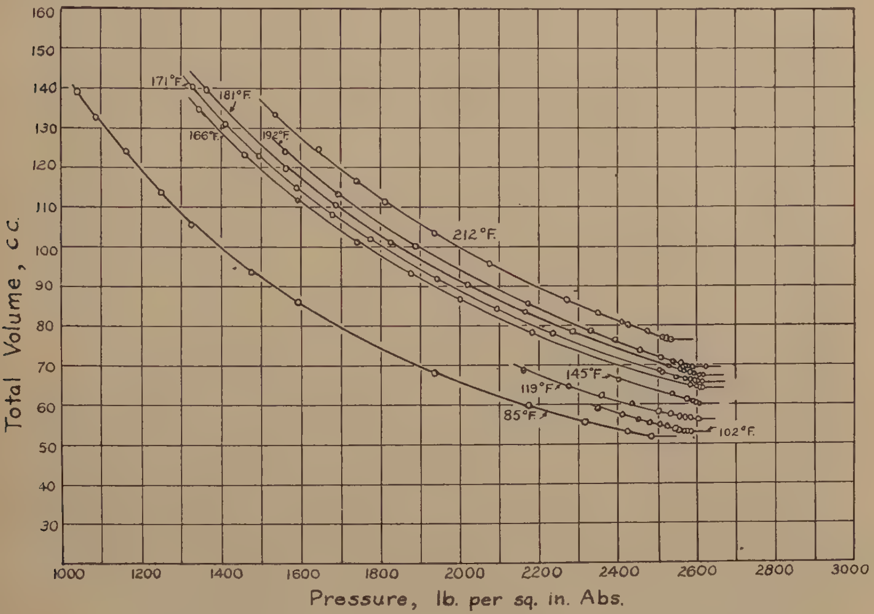

FIG. 4.—PRESSURE-VOLUME ISOTHERMS OF TWO-PHASE SYSTEM.

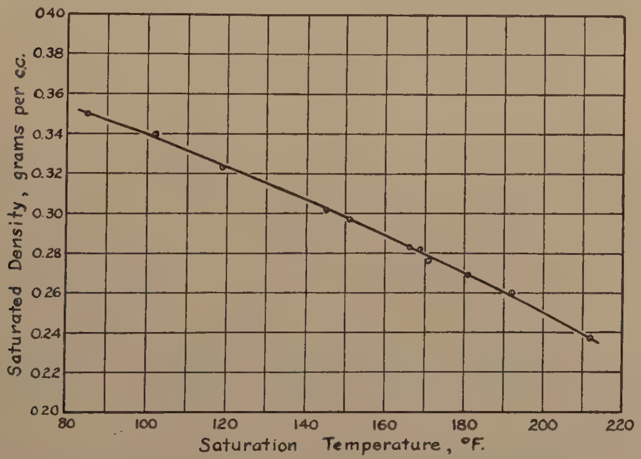

FIG. 5.—DENSITY OF SYSTEM AT BUBBLE POINTS AND DEW POINTS.

Upon adding a proper ratio of the constituents at room temperature and pressures of the order of 1500 lb., four phases appeared to form; an upper gas phase; a low-density, nearly colorless liquid; a reddish brown denser liquid, and a sludge or plastic solid on the bottom of the container.

The transformation from the single-phase region to the two-phase region was observed for the less dense liquid and the gas phase with the usual brownish red color and without any apparent effect caused by the presence of the second liquid phase. The sludge or solid phase could be blown from the gauge under 1500 lb. pressure. The asphaltic substance so removed was accompanied by some gas but was solid at atmospheric conditions. The asphalt had a molecular weight of 979 as compared to 345 for the original crude, both measurements using the lowering of the freezing point of benzene.

ACKNOWLEDGMENT

The assistance of Fred Kurata in portions of the work is acknowledged.

REFERENCES

1. Bahlke and Kay: *Ind. and Eng. Chem.* (1932) **24**, 291.
2. Boomer, Johnson and Pierce: *Canadian Jnl. of Res.* B16 (1938) 319.
3. Boomer and Johnson: *Canadian Jnl. of Res.* B16 (1938) 328.
4. Boomer, Johnson and Pierce: *Canadian Jnl. of Res.* B16 (1938) 396.
5. Carter and Webber: *Ref. and Nat. Gas Mfr.* (1939) **18**, 206.
6. Cummings, Stone and Volante: *Ind. and Eng. Chem.* (1933) **25**, 728.
7. Gilliland, Lukes and Sheeline: *Trans.* A.I.M.E. (1939) **132**, 132.
8. Katz and Singleterry: *Trans.* A.I.M.E. (1939) **132**, 103.
9. Katz: Amer. Petr. Inst. Drill. and Prod. Practice (1938) 435.
10. Kay: *Ind. and Eng. Chem.* (1938) **30**, 459.
11. Kay: Baltimore Meeting, Amer. Chem. Soc., Petr. Div., April 1939.
12. Kuenen: *Phil. Mag.* (1895) **40**, 173.
13. Roess: *Jnl.* Inst. Petr. Tech. (1936) **22**, 665.
14. Sage, Schaafsma and Lacey: *Ind. and Eng. Chem.* (1934) **26**, 214.

DISCUSSION

(*Charles Warner presiding*)

E. A. STEPHENSON,* Lawrence, Kansas.—The phase diagram presented by Dr. Katz deals with an actual natural gas-natural gasoline system, such as is found in many of our distillate pools where no oil is known to be present, or where a gas gap occurs of such magnitude that its phase behavior resembles that of distillate pools.

In view of the current interest in this problem, it seems desirable to express the physiochemical relations in as many different ways as possible; hence the phase data that Dr. Katz has obtained are also presented as functions of the reduced pressure and reduced temperature. These are then plotted to the same scale on both ordinates, so as to eliminate the distortion that results through the use of scales based on pounds and Fahrenheit degrees.

With a critical pressure equal to 2615 lb. per sq. in., and the critical temperature equal to 169.5° F. (629.5 Rankine), it then appears that 0.1 of a unit of reduced pressure represents for graphical purposes 261 lb., and 0.1 of a unit of reduced pressure 63° Rankine. The distortions just mentioned are eliminated when reduced functions of pressure and temperature are used, as shown on Fig. 6.

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* Professor of Petroleum Engineering, University of Kansas.

However, even the modified phase diagram does not reveal the complete story of the relative effects of pressure and temperature changes. If possible, supplementary data on the specific heat of the various gases and liquids should be obtained, and an entropy-enthalpy diagram prepared for the gaseous and liquid components. This is by no means an easy task, since the composition of both gas and liquid change with each change in pressure and temperature.

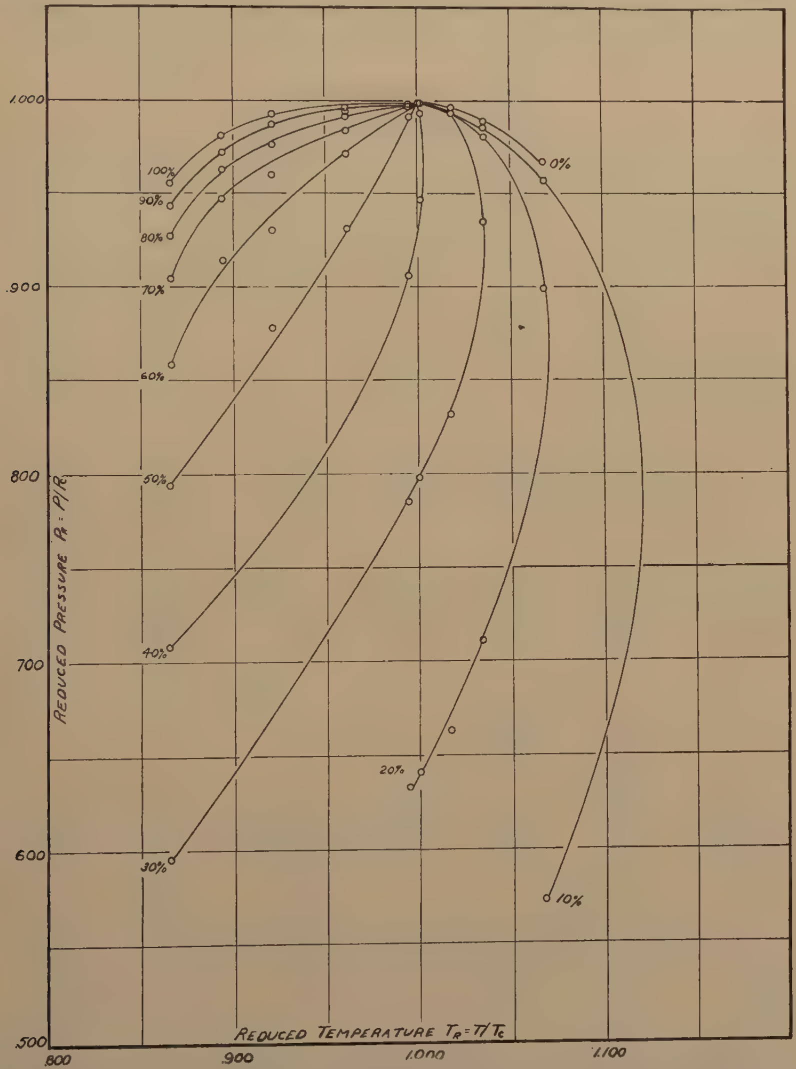

FIG. 6.—PHASE DIAGRAM OF SYSTEM COMPOSED OF NATURAL GAS AND NATURAL GASOLINE USING REDUCED PRESSURES AND TEMPERATURES. PERCENTAGES REFER TO LIQUID VOLUME.

P_c = 2615 lb. per sq. in. abs.; T_c = 169.5° F.

Attention might be called to the greater importance of pressure changes in the general range of 0.9 to 0.96 reduced pressure and 0.9 to 1.0 reduced temperature. On the other hand, where the temperatures are above $1.0P_r$, and the pressures below $0.9P_r$, the greater influence of temperature change becomes obvious.

Finally, Dr. Katz should be complimented for this excellent contribution to one of the difficult problems which petroleum engineers face today; i.e., the phase behavior of high-pressure wells. Gradually the technique is being developed for the correct solution of the problem.

Fundamental Phase Behavior of Hydrocarbons

By John E. Sherborne,* Junior Member A.I.M.E.

(Los Angeles Meeting, October 1939)

Much valuable scientific research has been performed in recent years on the subject of phase behavior of hydrocarbons.†[1–11] Engineers employed in petroleum production are interesting themselves in this work as well as in methods of applying the fundamental data available to the solution of their various problems.

Recently a number of papers have been published in which applications of phase behavior have been made to specific cases pertaining to critical phenomena.[12–16] Little effort, however, has been made in the literature to show the relation between changes occurring in the critical region and the more common phase behavior, therefore it is believed that a presentation of the fundamentals of phase behavior with reference to hydrocarbons is timely.

Study of phase behavior is not new. In the metallurgical field, knowledge of heterogeneous equilibria has advanced tremendously, particularly with reference to solid-solid and solid-liquid behavior. Much is known about vapor-liquid equilibria too, but few engineers are familiar with this subject.‡

Definition of Terms

In a discussion of this sort, a definition of terms used is most important. Such terms as "pressure," "temperature" and "volume" need little definition other than mention of the units in which they are considered. Pressure is expressed in pounds per square inch *absolute.* Temperature is usually expressed as degrees Fahrenheit or degrees Rankine. In considering thermodynamic and phase behavior, the use of the absolute, Rankine, scale is desirable. Volume is expressed as specific volume, such as cubic feet per pound. This will be recognized as the reciprocal of the specific weight. In considering systems composed of more than one component, it is sometimes desirable to consider molal

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* Petroleum Engineer, Union Oil Company of California, Compton, California.

† Notable among the various investigators are Sage, Lacey and co-workers, Katz and Lindsly. Only a few selected references of these and other authors will be used.

[1] Numbers refer to references at end of paper.

‡ Several books dealing with phase behavior are included in the bibliography.[16–20, 44]

or weight composition rather than volume. This will be considered more fully in discussing two-component systems.

System.—A system may be classified as a one, two, three, or multi-component system. From a strictly scientific point of view a component must be defined as a pure substance. Thus a system containing nothing but propane would be of one component, while one consisting of methane and propane would be of two components. It follows that even the simplest of crude oils and natural gases are multi-component systems. However, it is sometime practical, under a wide range of conditions, to consider naturally occurring hydrocarbon mixtures as two-component systems in which natural gas and crude oil are the respective components.

Phase.—Under the proper conditions, any system may exist as one or more phases. In the language of Willard Gibbs, a portion of matter homogeneous in the sense that its smallest mechanically isolable parts are indistinguishable from one another physically or chemically is a phase.

ONE-COMPONENT SYSTEM

In Fig. 1 is shown a generalized pressure-temperature diagram for a one-component system.* In it the lines represent the loci of equilibrium points. For example, any point on the line AB represents a condition of equilibrium between the solid and vapor phases for the particular pressure and temperature chosen. In like manner BD represents the solid-liquid equilibrium line while along the line BC liquid and vapor coexist. At no place does more than one phase exist except for the condition occurring at the boundary lines or their extensions, BF and BE, which represent the metastable states of supercooling and superheating, respectively. Thus, for the pressure P gas and liquid can exist together only at the temperature T.

Phase Rule

Fig. 1 shows that as long as only one phase exists there are within the limits of the boundaries of that phase for a given pressure an infinite number of values for the temperature. If two phases coexist, there is only one value of temperature for each value of pressure. Under such a condition, the system is said to have only one degree of freedom. In order for three phases to exist for a one-component system, the pressure and temperature are both fixed and the system is said to have no degrees of freedom. Physical behavior of this nature may be expressed as the phase rule, which may be given as:

$$P + F = 3 \qquad [1]$$

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* Fig. 1 represents projections of curved surfaces onto a plane. The diagram has been generalized in order to show various points of interest, consequently it is not drawn to a scale applicable to any given system.

where P = number of phases present
and F = number of degrees of freedom.

This rule can be more generally expressed as:

$$P + F = C + 2 \qquad [2]$$

where C = number of components.

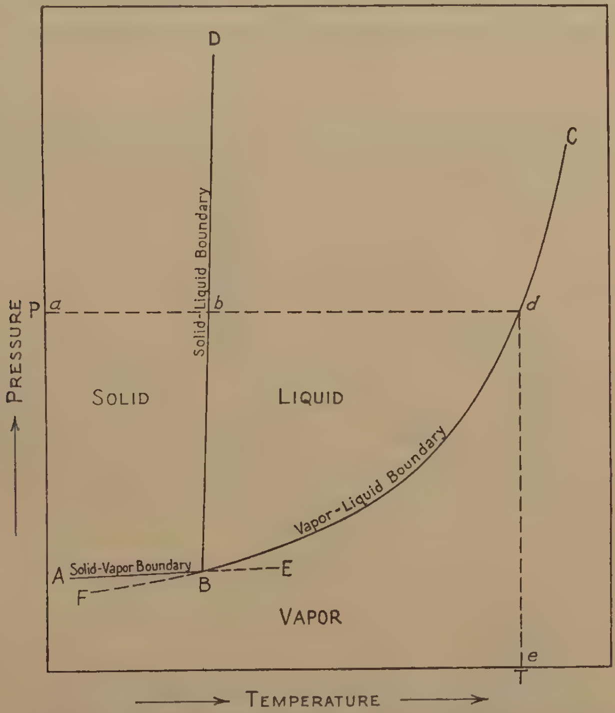

FIG. 1.—GENERALIZED PRESSURE-TEMPERATURE DIAGRAM FOR A ONE-COMPONENT SYSTEM.

While the phase rule in itself is of little practical significance, it clearly demonstrates that with an increasing number of components the number of possible combinations rapidly increases.

In this figure, there are two other points, B and C, which are of interest. Point B, commonly referred to as the "triple point," represents the state in which gas, liquid and solid phases all exist simultaneously. Here, it will be noted, there are no degrees of freedom, the pressure and temperature being fixed. Point C represents the critical state of the system. It is the temperature at which the properties of the liquid are identical with those of the gas. Since the pressure and temperature are fixed, here again no degrees of freedom exist and the state of the system is fixed. For a one-component system, the critical temperature is the highest temperature at which gas and liquid phases can both exist.

Since Fig. 1 shows only changes in pressure and temperature, an attempt has been made to show in Fig. 2 a series of surfaces representing the relation between changes taking place in the temperature, pressure and volume.[*]

Whether the system be in the solid, liquid or gaseous phase, a knowledge of the pressure, temperature and specific volume[†] is necessary and sufficient to completely establish the volumetric behavior of a one-component system. The relation may be expressed as

$$F(v, p, T) = 0 \tag{3}$$

For obvious reasons the surfaces in Fig. 2 have been restricted to finite values of the three variables. Hence, for the limited range of

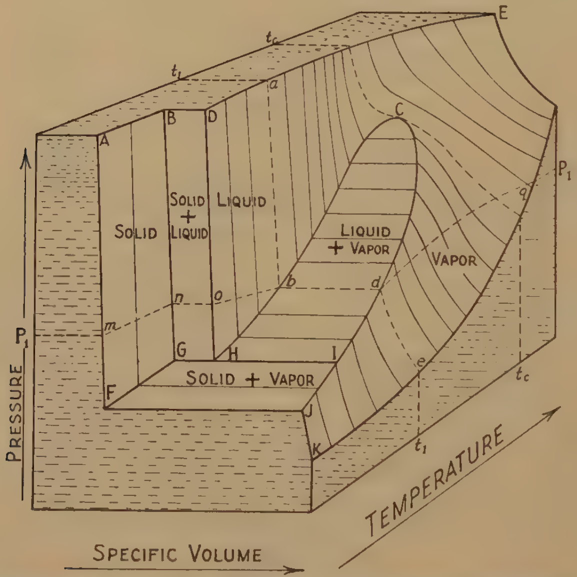

FIG. 2.—GENERALIZED PRESSURE-TEMPERATURE-VOLUME DIAGRAM FOR A ONE-COMPONENT SYSTEM.

pressure, temperature and volume covered by the surface *ABGF* only the solid phase exists, and in like manner, for the conditions represented by the surface *BDHG*, only solid and liquid phases coexist, and so on. The points *GHI* determine the triple-point line, all three points coinciding to form the point *B* in Fig. 1.

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[*] This diagram does not represent all known cases of one-component systems, water being one exception. However, it is applicable to most of the known pure substances.

[†] External fields of force, such as gravitational, electrical and magnetic and surface forces are assumed to be negligible. Unless otherwise noted, these assumptions will apply throughout this paper.

In general, only liquid, liquid-vapor and vapor phases need be investigated in considering hydrocarbon reservoir systems. Of particular interest is the region bounded by HCI, which represents the two-phase region, liquid plus vapor. Starting with the system at point a, in which condition it is all liquid at high pressure, holding the temperature constant at t_1 and reducing the pressure from a to b results only in a change in the volume of the liquid until at b evaporation starts. The volume of the system increases at constant pressure from b to d until at d only an infinitesimal amount of liquid remains. Isothermal expansion of the gas takes place from d to e.

From the slope of the lines ab and de the compressibility of the liquid and gas respectively can be obtained. In the two-phase region the compressibility derivative becomes infinite. This derivative may be expressed as follows:

$$\text{Compressibility } (\beta) = -\left(\frac{\delta V}{\delta P}\right)_T \qquad [4]$$

In a similar manner, from the slopes of the lines shown by mn, no, ob, bd and dq, which represent isobaric changes in the volume of the system with temperature, the coefficients of expansion of the system for the conditions existing in the respective region chosen can be obtained. That is, from the slope of a line such as ob we obtain the expression:

$$\text{Thermal expansion } (\alpha) = \left(\frac{\delta V}{\delta T}\right)_P \qquad [5]$$

In Fig. 2 the critical point is given by C. At and above the critical temperature t_c it is not possible to distinguish between liquid and vapor. The fact that at the critical point the pressure, temperature and volume are fixed is shown.

TWO-COMPONENT SYSTEM

The phase rule shows that for a two-component system it is possible for four phases to coexist. These may be any combination of liquid, solid or vapor, including four solid or four liquid phases. However, there have never yet been found more than two liquid phases coexisting in a two-component system. Although the production of oil from deeper zones of higher pressures and temperatures may disclose the coexistence of two or more liquid phases, this discussion will be restricted to the behavior of systems more common at the present time, those having only one liquid phase. Specifically, hydrocarbon systems as they occur in the reservoir will be considered to consist of varying mixtures of the component natural gas and the component crude oil.

Phase changes of a two-component system can best be shown by pressure, temperature and composition diagrams. While in some cases the use of molal composition is desirable, for practical purposes weight composition is most convenient. Using weight composition the crude oil or natural gas may be expressed as a percentage of the total weight of the system. This can be directly related to the gas-oil ratio providing the system is always assumed to be composed of two components. Unless it is stated otherwise, the weight composition will be used throughout the remainder of the paper.

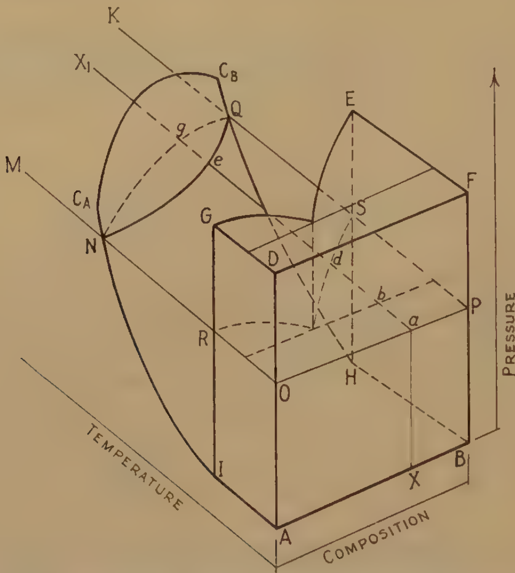

FIG. 3.—GENERALIZED PRESSURE-TEMPERATURE COMPOSITION DIAGRAM FOR A TWO-COMPONENT SYSTEM.

In Fig. 3, based on a diagram by Roozeboom,[20] is shown a three-dimensional representation of the pressure, temperature, composition relations of a two-component system for which there is only one liquid phase.* The graph is plotted in rectangular coordinates in which the ordinate is pressure while the abscissae are composition and temperature. Point A represents 100 per cent of the pure substance A, natural gas, while point B represents 100 per cent of the pure substance B, crude oil. Point X represents a mixture of A and B of which the fraction XB/AB is component A, and the fraction XA/AB is component B. It should be realized that the solid-liquid equilibria depicted in Fig. 3 are not descriptive of crude oil-natural gas systems.

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* Fig. 3 is a generalized diagram and is not drawn to scale for any specific binary system. The pressure and temperature of points A and B are shown at some value above zero, and in order to avoid confusion resulting from too many lines, many of the details pertaining to the solid and associated phases in the region of low pressures have been omitted.

A plane through the points C_A*NIAODG* represents the pressure-temperature diagram for the pure substance *A*; likewise the points C_B*QHBPFE* represent the pressure-temperature diagram for the pure substance *B*. These points, if projected onto one plane, give the diagram shown in Fig. 4. The similarity between Fig. 4 and Fig. 1 can be seen readily. Since for a given temperature the vapor pressure of the substance *A* is greater than that for *B*, *A* is the more volatile and, consequently, represents gas in the gas-crude oil system.

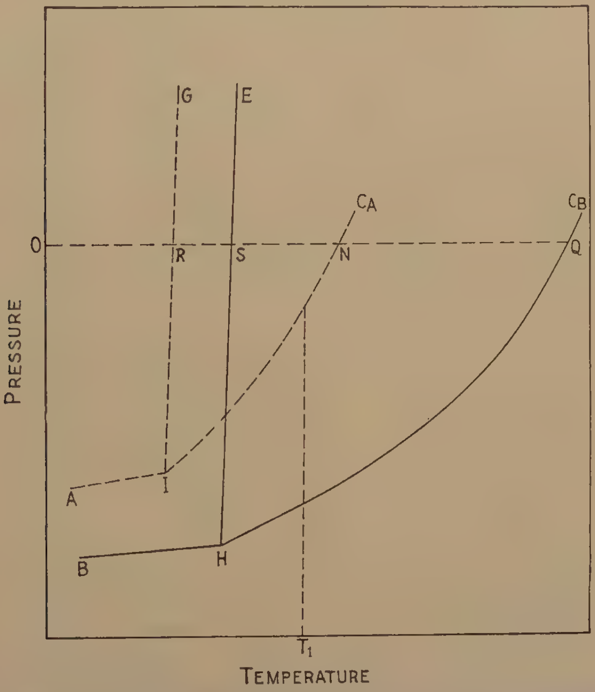

FIG. 4.—PROJECTION OF LIMITING COMPOSITION CURVES FOR TWO-COMPONENT SYSTEM ONTO PRESSURE-TEMPERATURE PLANE.

Before considering pressure-temperature diagrams for mixtures of *A* and *B*, it is desirable to orient the phases on an isobaric graph of composition and temperature taken at pressure *P*. This is represented by the plane *MNOPQK* in Fig. 3 and is shown in Fig. 5. Choosing a composition represented by point *a*, Fig. 5, and following the changes of state that take place when the temperature is increased, one follows the line *abcdefgp*. The region *ab* represents a solid composed of a mixture of the two components in the proportion given by the composition *a*. At *b*, liquid of the composition *y* starts to appear until the solid in equilibrium with the liquid is pure, solid B. As the system changes from b to d the composition of the liquid follows the path yhd until at d all of the solid B disappears and liquid of the composition a exists from d to e. At point c, liquid of the composition given by h occurs in equilibrium with the solid B. The weight fraction of liquid present is given by the ratio $ci:hi$, while the proportion of the mixture that is solid is $ch:hi$. At point e gas of composition shown by o starts to form and from e to g the composition of the vapor phase follows the path omg, while the liquid in equilibrium with it follows the path enq. At f an amount of gas of composition m, the weight fraction of which is expressed by the ratio fn/nm, is in equilibrium with liquid of the composition n, which exists in the proportion given by the ratio fm/mn. A trace of liquid of the composition q coexisting with gas of composition a exists at g. From g to p there is only gas.

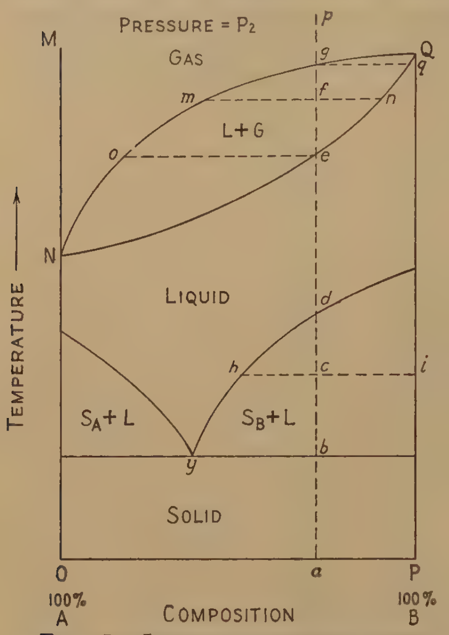

Fig. 5.—Isobaric composition-temperature section showing condition of two-component system shown in Fig. 3 when pressure equals P.

Two points, e and g, have special significance in petroleum production, for they represent the bubble point and the dew point, respectively. *The bubble-point state is that in which an infinitesimal amount of gas exists in equilibrium with the liquid phase*, and in like manner, *the dew-point state is that in which an infinitesimal amount of the liquid is in equilibrium with the vapor phase.* The temperature at point e is commonly known as the "bubble-point temperature" and is defined as follows:

The bubble-point temperature is that temperature at which there is an infinitesimal amount of gas in equilibrium with the liquid phase, for a given pressure and composition.

In like manner, the temperature at point g is known as the "dew-point temperature," and is defined as follows:

The dew-point temperature is that temperature at which there is an infinitesimal amount of liquid in equilibrium with the vapor phase, for a given pressure and composition.

It also is possible to speak of bubble-point pressure and bubble-point composition. Bubble-point composition may be expressed as bubble-point gas:oil ratio. The dew point may be treated in the same manner.

In Fig. 6 is shown a temperature-molal composition diagram of the vapor-liquid region for the system methane-propane as it is at a pressure

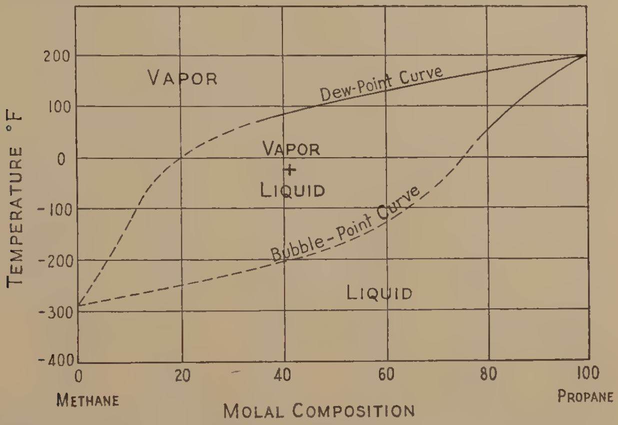

FIG. 6.—TEMPERATURE-COMPOSITION DIAGRAM FOR TWO-COMPONENT SYSTEM, METHANE-PROPANE AT 600 LB. PER SQ. IN. PRESSURE.

Solid lines based on data from Sage, Lacey and Schaafsma (methane value from J. H. Perry, Handbook Chem. Eng., 619. New York, 1934. McGraw-Hill Book Co.).

of 600 lb. per sq. in. absolute. Only the value for pure methane[22] and the values above 70°F.[10] are experimentally correct. The dotted lines are used solely to show the general nature of the vapor-liquid region.

A three-dimensional diagram of the liquid-vapor region for a two-component system is shown in Fig. 7. In it, the lines *DLE*, *FMG*, *HNI*, etc., represent bubble-point curves for the temperatures T_0, T_1 and T_2, respectively. A movement along any one of these lines would represent an isothermal change in bubble-point pressure with composition for the particular temperature chosen.

In like manner, the lines *DQE*, *FPG*, *HOI*, etc., represent the dew-point curves for the respective temperatures.

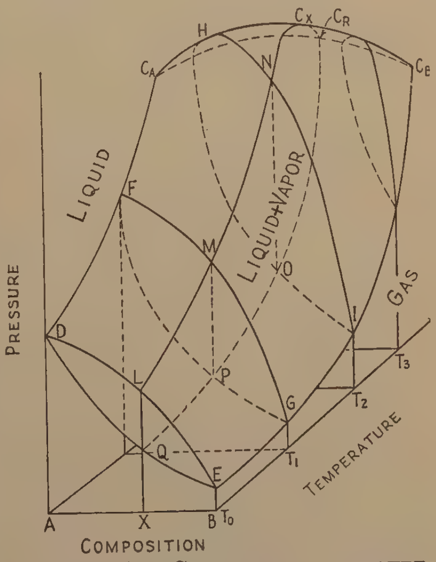

FIG. 7.—GENERALIZED PRESSURE-TEMPERATURE-COMPOSITION DIAGRAM OF TWO-COMPONENT SYSTEM IN RANGE OF CONDITIONS USUALLY FOUND IN PETROLEUM RESERVOIRS.

Fig. 8 shows an isothermal section of composition versus pressure at the temperature T_1, Fig. 7. Here again the ordinate *AF* represents pure component *A* and *BG* represents pure substance *B*. Points *F* and *G* are the vapor pressures of the pure substances *A* and *B*, respectively, at the temperature for which the section is taken.

If a composition *X* is chosen and the pressure increased, the system starts as a gas and undergoes no change, except in volume, until at the point *P* where an infinitesimal volume of liquid of composition *d* forms. This is the dew-point pressure. A further increase in pressure results in the formation of more liquid of a composition given by some point on the curve from *d* to *M* in equilibrium with gas given by some point on the curve between *P* and *e*. At *b* the weight fraction *bc*/*ac* of gas of composition *a* is in equilibrium with the weight fraction *ab*/*ac* of liquid of composition *c*. The total composition of the system is still given by *X*. By increasing the pressure still more, further quantities of the gas are liquefied, until at *M* there is only an infinitesimal amount of gas in equilibrium with the liquid. This is the bubble-point pressure, for the temperature and composition in question.

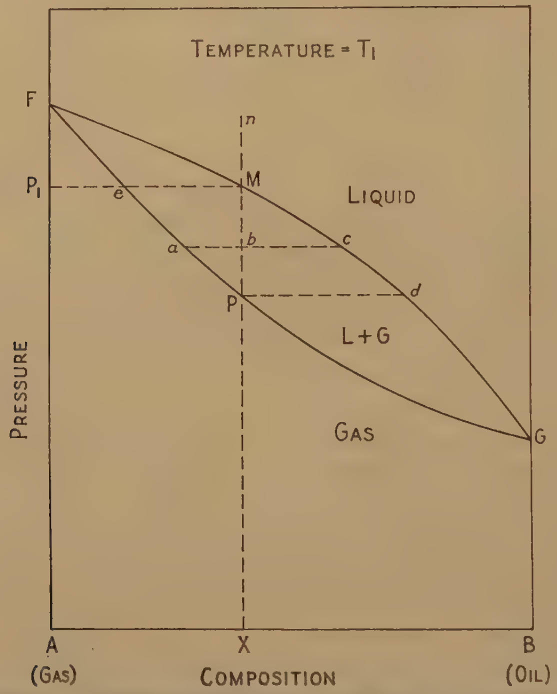

FIG. 8.—ISOTHERMAL PRESSURE-COMPOSITION DIAGRAM FOR HYPOTHETICAL CRUDE OIL-NATURAL GAS SYSTEM AT TEMPERATURE T_1.

Referring again to Fig. 7, the line DFC_A represents the vapor-pressure curve for the component *A* and the line $EGIC_B$ the vapor-pressure curve for the component *B*. If a mixture of *A* and *B* having a composition *X* is selected, the vapor-temperature relations will be expressed by the

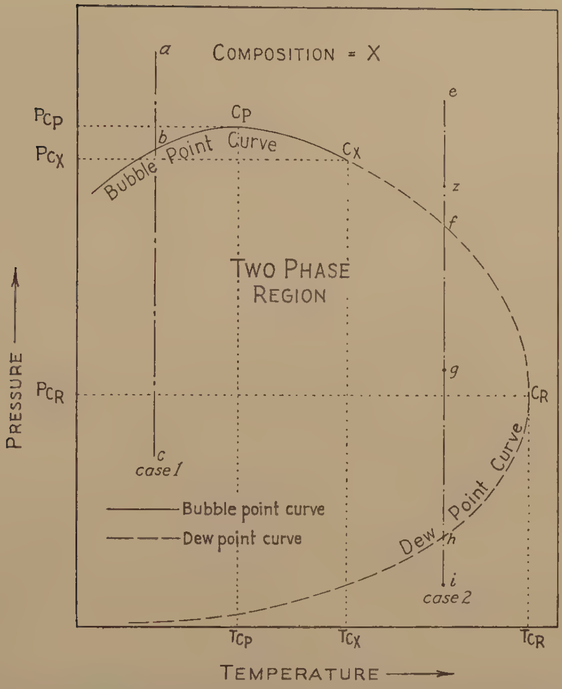

FIG. 9.—PRESSURE-TEMPERATURE SECTION FOR CONSTANT COMPOSITION X OF HYPOTHETICAL CRUDE OIL-NATURAL GAS SYSTEM.

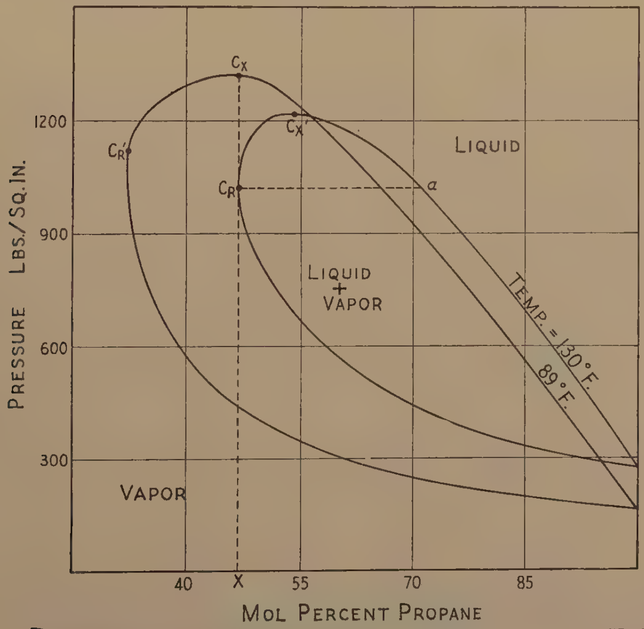

FIG. 10.—PRESSURE-COMPOSITION DIAGRAM FOR METHANE-PROPANE SYSTEM. *(After Sage, Lacey and Schaafsma.)*

plane $LMNC_XC_ROPQ$ instead of a line. Points C_A and C_B are the critical points of the pure components A and B, respectively. The critical point of the mixture is C_X; and for the example given it occurs at a higher pressure and temperature than that of the more volatile component. The behavior shown in Fig. 7 is typical of that generally encountered in binary paraffin hydrocarbon systems.

Line $C_AC_RC_B$ is the locus of points of maximum temperature for the two-phase region. Point C_R, which is known as the *cricondentherm*,[1] or critical condensation temperature, is the highest temperature at which liquid and vapor coexist for the mixture of composition X. As previously defined, for a one-component system the critical temperature was the highest temperature at which the liquid and gas could occur together in equilibrium. It was also defined as the temperature at which the liquid and vapor phases were identical.

For a system composed of any number of components, *the critical temperature is always the temperature at which the liquid and vapor phases have identical properties.* That it is not the maximum temperature at which the liquid and vapor phases can coexist for systems of two or more components is illustrated in Fig. 9, which is a pressure-temperature section for the system in Fig. 7 at the composition X. The critical point, C_X, occurs at a lower temperature than does the cricondentherm C_R.

Because it is not possible to show by means of Fig. 9 that the properties of the liquid and gas are not identical at the cricondentherm, a pressure-composition diagram, Fig. 10, for the two-component system methane-propane[9] was constructed using two constant-temperature curves which were selected so that the points C_X and C_R correspond to the composition X of Fig. 9. By the use of ratios, as employed in the discussion of Figs. 3 and 5, it can be shown that at C_X the composition of the liquid is identical with that of the gas. This occurs at 89°F., while the cricondentherm C_R occurs at 130°F. At this latter point there is an infinitesimal amount of liquid of composition given by point a in equilibrium with gas of composition X. Fig. 10 fails to show that the liquid and gas can coexist at a pressure higher than that at the critical point. This point, the maximum pressure at which two phases can coexist, is shown by C_P in Fig. 9. For a one-component system, the points C_P, C_X and C_R coincide to form one point.

ILLUSTRATIVE PHASE CHANGES IN OIL AND GAS PRODUCTION

It is convenient to assume that Fig. 9 represents a system of natural gas and crude oil, in considering what happens in production from a reservoir. In one case, illustrated by the line *abc*, there is liquid* (oil) under a high pressure and at a temperature higher than surface temperature but not higher than the critical temperature. No free gas exists. As the fluid rises in the well there is a decrease in pressure, from *a* to *b*, until at *b* gas starts to separate. This is the bubble point for the pressure and temperature shown. As fluid approaches the surface, the pressure continues to decrease and more and more gas comes out of solution until at the surface the point *c* is reached. While it is recognized that a temperature decrease occurs in the system between the reservoir and the surface, this change has been considered negligible for the purposes of this and the following illustrations.

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* Near the critical region it is difficult to distinguish between liquid and gas in the single-phase region. However, since at the bubble point *b* there forms an infinitesimal

In the second case, one in which the reservoir has a pressure similar to that of the first but a temperature above the critical temperature of the hydrocarbon system, only the gaseous phase* exists in the reservoir. This condition is shown by *e*. In coming to the surface the gas undergoes only a relatively small drop in pressure and no fluid appears. This is represented by some point *z* on the path of *ef*. If the pressure is decreased more, liquid starts to condense at *f* and greater quantities of liquid form with further decrease in pressure, until at some point *g* a maximum amount of liquid condenses. Any further decrease in pressure results in a decrease in the amount of the liquid phase until the dew point is reached at *h*. At this point, the final drop of liquid vaporizes and only gas remains. This phenomenon, resulting in the formation of a liquid phase followed by its disappearance as a result of progressive increase or decrease in pressure, under these conditions of restraint, on a system of constant composition, has been called *retrograde condensation.*[18]

It is important to note that retrograde phenomena may occur as a result of change in pressure or temperature, but only when the composition of the system remains constant. Changes in the reservoir condition that result from the selective withdrawal of either gas or oil cannot be classed as retrograde phenomena, although there is an apparent similarity.

Formation Volumes.—While the use of composition is convenient in illustrating changes that take place in multi-component systems, the effects that changes in pressure and temperature have on the volume of constant or variable composition systems are of particular practical significance. The term "formation volume" as used is the ratio of the volume occupied by the hydrocarbons at subsurface equilibrium temperature and pressure to a unit volume of oil as measured at 60°F. and a pressure of 14.73 lb. per sq. in. abs. Liquid shrinkage is sometimes used instead of formation volume and may be defined as its reciprocal.

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amount of the vapor phase, and at the dew point *f* there forms an infinitesimal amount of the liquid phase, it is convenient to assume that the single-phase fluid at the point *a* is liquid and that the phase at *e* is gaseous.

* See preceding footnote.

VISCOSITY

Closely allied with phase behavior in the treatment of petroleum-production problems is the effect upon the viscosity of the crude resulting from changes in pressure, temperature and composition. Since a number of papers have been published regarding this effect,[7,23–30] it will suffice at this time to point out that as much as eightfold changes in viscosity can occur throughout the ranges in pressure, temperature and composition commonly occurring under producing conditions.

PRACTICAL APPLICATIONS

The applications of phase behavior to practical field problems are numerous, and have been discussed by many writers.[31–43] A review of these applications is beyond the scope of this paper, but it should be noted that in studies of reservoir conditions, in volumetric estimate of reserves, and in problems involving both homogeneous and heterogeneous flow, a knowledge of phase behavior for the hydrocarbon system involved is requisite.

SELECTED BIBLIOGRAPHY

1. L. W. T. Cummings, F. W. Stones and M. A. Volante: *Ind. and Eng. Chem.* (1933) **25,** 728.
2. P. Duhem: *Jnl. Phys. Chem.* (1897) **1,** 273.
3. J. E. Gosline and C. R. Dodson: Amer. Petr. Inst. Drill. and Prod. Practice (1938) 423.
4. J. P. Kuenen: *Ztsch. Phys. Chem.* (1893) **11,** 38.
5. *Ibid.* (1897) **24,** 667.
6. B. E. Lindsly: *Petr. Engr.* (Feb., 1936) **7,** 34.
7. B. H. Sage and W. N. Lacey: Amer. Petr. Inst. Drill. and Prod. Practice (1935) 141.
8. *Ibid.* (1936) 158.
9. B. H. Sage, W. N. Lacey and J. G. Schaafsma: *Ind. and Eng. Chem.* (1934) **26,** 214.
10. B. H. Sage, W. N. Lacey and J. G. Schaafsma: Amer. Petr. Inst. *Prod. Bull.* 212 (1933) 119.
11. H. S. Taylor, G. W. Wald, B. H. Sage and N. N. Lacey: *Oil and Gas Jnl.* (Aug. 10, 1939) **38,** 46.
12. E. O. Bennett: *Petr. Engr.* (mid-year, 1939) **10,** 50.
13. C. R. Horn: *Oil Weekly* (Sept. 11, 1939) **95,** 27.
14. D. L. Katz: Amer. Prod. Inst. Drill. and Prod. Practice (1938) 435.
15. D. L. Katz and C. C. Singleterry: *Trans.* A.I.M.E. (1939) **132,** 103.
16. F. V. L. Patten and C. I. Denny: *Oil Weekly* (Dec. 12, 1938) **92,** 21.
17. A. Findley and A. N. Campbell: The Phase Rule and its Application. New York, 1938. Longmans, Green and Co.
18. J. P. Kuenen: Verdampfung und Verflüssigung von Gomishen. Leipzig, 1906. Barth.
19. A. C. D. Rivett: The Phase Rule. London, 1923. Oxford Univ. Press.
20. B. Roozeboom: Die Heterogenen Gleichgewichte vom Standpunkte der Phasenlehre, II. Braunschweig. Viewig und Sohn.

21. H. S. Taylor: Treatise on Physical Chemistry. New York, 1935. D. Van Nostrand Co.
22. J. H. Perry: Chemical Engineering Handbook, 619. New York, 1934. McGraw-Hill Book Co.
23. C. E. Beecher and I. P. Parkhurst: Petr. Dev. and Tech. in 1926, A.I.M.E. (1927) **G26,** 51.
24. B. H. Sage and W. N. Lacey: *Ind. and Eng. Chem.* (1938) **30,** 829.
25. B. H. Sage and W. N. Lacey: *Trans.* A.I.M.E. (1938) **127,** 118.
26. B. H. Sage, B. N. Inman and W. N. Lacey: *Ind. and Eng. Chem.* (1937) **29,** 888.
27. B. H. Sage, W. R. Mendenhall and W. N. Lacey. Amer. Petr. Inst. *Prod. Bull.* 216 (1935) 45.
28. B. H. Sage, J. E. Sherborne and W. N. Lacey: *Ind. and Eng. Chem.* (1935) **27,** 954.
29. B. H. Sage, J. E. Sherborne and W. N. Lacey: Amer. Petr. Inst. *Prod. Bull.* 216 (1935) 40.
30. B. H. Sage, W. D. Yale and W. N. Lacey: *Ind. and Eng. Chem.* (1939) **34,** 223.
31. B. B. Boatright: *Trans.* A.I.M.E. (1932) **98,** 295.
32. S. E. Buckley: *Trans.* A.I.M.E. (1938) **127,** 178.
33. E. V. Foran: *Trans.* A.I.M.E. (1939) **132,** 22.
34. D. L. Katz: *Trans.* A.I.M.E. (1936) **118,** 18.
35. D. L. Katz: *Trans.* A.I.M.E. (1938) **127,** 159.
36. D. L. Katz and K. H. Hackmuth: *Ind. and Eng. Chem.* (1937) **29,** 1072.
37. W. N. Lacey: Amer. Petr. Inst. *Prod. Bull.* 210 (1932) 16.
38. W. K. Lewis: *Trans.* A.I.M.E. (1934) **107,** 11.
39. B. H. Sage and W. N. Lacey: Amer. Petr. Inst. Drill. and Prod. Practice (1935) 107.
40. B. H. Sage and W. N. Lacey: Amer. Petr. Inst. *Prod. Bull.* 216 (1935) 50.
41. B. H. Sage and W. N. Lacey: Amer. Petr. Inst. Drill. and Prod. Practice (1937) 81.
42. B. H. Sage, B. L. Hicks and W. N. Lacey: Amer. Petr. Inst. Drill. and Prod. Practice (1938) 386.
43. R. J. Schilthuis: *Trans.* A.I.M.E. (1936) **118,** 33.
44. B. H. Sage and W. N. Lacey: Volumetric and Phase Behavior of Hydrocarbons. Stanford University, 1939. Stanford Univ. Press.

DISCUSSION

(R. W. French, Jr., presiding)

C. R. Dodson,* La Habra, Calif.— This paper is a concise survey of the thermodynamic behavior of natural hydrocarbon mixtures. We spend a great deal of money on the experimental investigation of such problems and we are just beginning to obtain relationships that are useful to field engineers. The problems are, of course, extremely important to the management in determining the proper development and production programs, such as the amount of oil recoverable in any tract, well spacing, the behavior of the fluid with pressure decline, etc. In reference to the use of some of the data that have been published, a word of caution is essential. I might refer to the last issue of the A.P.I. proceedings, "Drilling and Production Practice 1938," in which there is a discussion of a paper that was published by the Standard Oil Co. Some comments by Mr. Buckley, of the Humble Oil Co., in the same volume, in which he shows that fluids produced under almost identical conditions may vary 60 per cent in solution gas and 100 per cent in bubble-point pressures are interesting.

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* Standard Oil Co.

N. Johnston,* Los Angeles, Calif.—There has long been a need for a clear, general treatment of the theory of phase behavior, to assist in the understanding and utilization of the voluminous and excellent contributions of Sage and Lacey, Katz and others. The present paper by Sherborne certainly appears to fill that need admirably, and will be used as a reference or introductory chapter to much of the work that is being presented in the literature.

Many applications of data on phase behavior can be cited now, and others undoubtedly will appear when annual withdrawals begin to exceed discoveries. The following are typical questions, which can best be answered by phase-behavior computations: What minimum bottom-hole pressure must be maintained to avoid bubble resistance in the sand? What reservoir volume was occupied by known quantities of oil and gas produced from a given zone? Under what conditions of withdrawal will retrograde condensation occur in the sand? The design of equipment, such as vapor recovery systems, pressure vessels, traps, gas anchors, etc., should be improved by a broader knowledge of the physical behavior of gas-oil mixtures, and Mr. Sherborne's article will certainly tend to broaden that knowledge.

W. L. Jarvis, Los Angeles, Calif.—The application of phase behavior is an integral part of estimating reserves of industrial properties or fields by means of volumetric methods. Under former methods of production where properties were rapidly developed and production allowed to continue at relatively unrestricted rates, production-decline curves could be satisfactorily used in making reserve estimations. Under conditions prevalent in the oil industry at the present time, low rates of withdrawal from fields are necessary. Coupled with this fact, new productive areas are not, in general, developed as rapidly as under former conditions. Since it is necessary to have reliable reserve data for orderly planning of the exploitation of reserves, for depreciation and depletion purposes, and for general long-range planning and policy making, it is now necessary to replace the production rate, decline-curve method of estimating reserves, by some other method. This of course, applies mainly to the newer productive areas.

The soundest way to estimate these newer reserves is believed to be by volumetric methods. This procedure consists of determining an estimate of the amount of oil underlying a field or property and then applying a recovery factor to obtain an estimate of the producible reserves. These recovery factors can be estimated in a number of ways. We believe this estimation of recovery factor is the weakest point in estimating reserves by volumetric methods. It is beyond the scope of this discussion to comment further on recovery factor except to say that we are working on this subject for some of the older fields and may at some future time have enough data to present in paper form.

In determining the amount of oil and/or gas in place, the void volume is computed from average porosity figures. Allowance is then made for the amount of water that is connate within the sands. Data on fluid content, porosity, and permeability are obtained through the medium of core analysis. The connate water content, unless tracers in the drilling fluid or oil base mud are used, is usually available only from generalized correlations.

The next step in estimating reserves by volumetric methods is where the pressure, volume, and temperature relationships are used. Mr. Sherborne has described the terms "formation volume factor" and "liquid shrinkage factor," the latter being the reciprocal of the formation volume factor. Since a barrel of oil, measured under surface conditions when in the reservoir with its constituent gas, occupies more than a barrel of space within the reservoir, the void volume in the reservoir available to oil and gas must be divided by the average formation volume factor, or multiplied by the shrinkage factor, in order to obtain the barrels of oil present under reservoir conditions. The formation volume factor depends on the formation pressure, temperature, and composition and relative amounts of the oil and gas contained in the reservoir. From this point in the estimation, only a recovery factor is needed to obtain an estimate of the reserves.

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* General Petroleum Corporation of California.

A knowledge of "P.V.T." data is important in determining the number of phases present within the reservoir. If the bubble-point or saturation pressure is below or lower than the bottom-hole producing pressure, gas does not separate from the liquid phase until it has risen in the hole and reached a depth where the pressure has been reduced to or below the bubble point. Under such conditions the motivating force causing the oil to enter the well bore is due to water drive. Since recovery from water-flushed sands is higher than from sands where gas drive alone has operated, under the above condition, a higher recovery factor in estimating reserves would be applicable.

In the distillate fields of the Gulf Coastal area, where there is no evidence of black oil in contact with the gas phase, and for wells producing from gas caps, where no liquid phase is present under reservoir conditions, a knowledge of pressure-volume-temperature relations, while necessary in the estimate of reserves by volumetric methods, may have additional value. A particular added value applies when retrograde condensation is possible, for the system may be outside the range of retrograde phenomena. If such flow conditions are present, it should be possible to regulate the well so that the maximum amount of liquid will occur at or near the gas traps, with a consequent justification of enlarging the recovery factor. In any event, if conditions are maintained so that no liquid separates in the formation, this added enlargement of recovery factor is justified. This is true because of the fact that less formation energy is expended in gas flow as compared with oil flow.

To date, volumetric behavior and solubility relation work have not been extensive and the results published or made available for general use have been confined to but few fields. At present the California Institute of Technology at Pasadena and the Standard Oil Company of California, at its West Coyote field in Orange County, have the only equipment in the West capable of satisfactorily determining these data. This equipment is elaborate and rather expensive, but the data obtained are so valuable for numerous applications that there is certainly justification for further installations so that a larger volume of data can be obtained. At present, if pressure-volume-temperature data are not available on the field in question, it is necessary to use data obtained under similar conditions of temperature, pressure, gravity, and gas-oil ratio from fields where such work has been performed and is available. This practice is likely to introduce some error, for the results would not necessarily be identical. For this reason pressure-volume-temperature work should be performed on the oil and gas from all fields where volumetric estimates are to be made, in order to obtain accurately their solubility relations and volumetric behavior.

Apparatus for Study of Pressure-volume-temperature Relations of Liquids and Gases

By B. H. Sage,* Member A.I.M.E., and W. N. Lacey*

(Los Angeles Meeting, October 1939)

An apparatus is described for the measurement of the pressure-volume-temperature relations of pure substances, simple mixtures and complex mixtures with an over-all absolute uncertainty, which is usually not more than 0.2 per cent. The equipment is suitable for studies in the gaseous, two-phase, and liquid regions. The behavior of such systems may be investigated at pressures as high as 10,000 lb. per sq. in. for temperatures between 70° and 600° F. The methods of measurement and the construction of the apparatus are described in some detail.

The measurement of the volumetric behavior of multicomponent systems requires the simultaneous measurement of the pressure, volume, temperature and weight of each component of the system. In the present apparatus a sample having constant weight is investigated at a number of independently controlled pressures and temperatures, therefore it is necessary only to establish the weight of each component added before a given set of measurements. This method is in distinction to that in which the total volume remains constant and the pressure is varied by addition or removal of material, the system having variable weight. An objective in the design of the apparatus to be described was to develop equipment that would yield results involving no uncertainties larger than 0.25 per cent throughout the range of pressures from 150 to 10,000 lb. per sq. in. at temperatures between 70° and 600° F. Although this over-all absolute uncertainty of measurement may not appear to be small, it necessitated care in the plans for control and measurement of each of the fundamental variables. In general, any uncertainty greater than 0.05 per cent in the pressure, volume, absolute temperature or weight of each component was considered undesirable; therefore the attempt was made to obtain a precision of measurement in each case such that the absolute uncertainty would be only half this amount except in certain regions near the ends of the experimental range of the variable under consideration.

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GENERAL ARRANGEMENT

In essence, the apparatus consists of a U-tube, closed at each end, which is partly filled with a constant amount of mercury. In one arm the sample is confined, while air under pressure may be admitted to the other in order to change the volume of the sample. The elevation of the mercury surface in the latter chamber is determined. The temperature of the arm containing the sample is controlled by surrounding it with a bath whose temperature can be held constant at any value within the range of the investigation.

The arrangement of the equipment is shown in a schematic manner in Fig. 1. The sample under investigation is confined within the chamber *C*, whose effective volume may be varied by the addition or withdrawal of mercury from the chamber *G*. Each of the chambers is 3 in. in inside diameter and has an effective length of 8 in. Equilibrium within and between the phases of the material in chamber *C* is obtained by means of a cage of six vertical rods, which is rotated by the magnetic agitator drive *P*, placed outside of the main thermostat. The entire space available to fluid inside this magnetic drive and the connecting tube *E* is filled with mercury. The agitator is rotated at approximately 100 r.p.m. and in most cases equilibrium between a nonviscous liquid and a gas phase is obtained in 10 or 15 min. The total quantity of mercury in the chambers *C* and *G* is constant and there is no opportunity for loss through packing glands and other possible sources of leaks. The chamber *G* is machined accurately and polished. The quantity of mercury in that chamber is determined by the elevation of the mercury surface therein. This is established by means of the movable electrical contact *F*, which

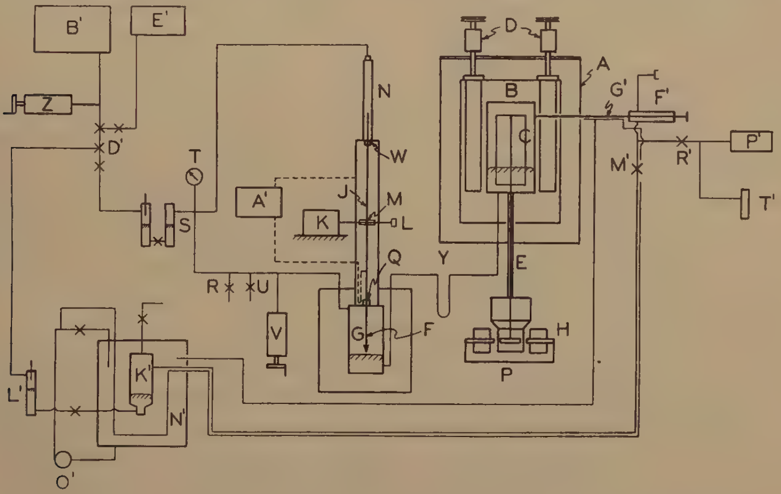

FIG. 1.—DIAGRAM OF THE APPARATUS.

enters the chamber *G* through the packing gland *Q*. The contact *F* is moved by means of the screw *J* and the nut *M* is driven by a worm operated from the motor *K*. The worm carries a counter *L*, which permits the estimation of the location of the mercury surface within 0.0002 in. One revolution of the counter corresponds to about 0.001-in. movement of the contact *F*. Dry carbon-dioxide-free air, from a supply at a pressure in excess of the maximum to be employed in the investigation, is admitted through the valve *R* to the upper part of the chamber *G*. The attainment of equilibrium in the chamber *C* of Fig. 1 is indicated by the constancy of the mercury height in the chamber *G*. The pressure existing within the chamber *G* is measured by means of a pressure balance connected to the gas phase of the chamber *G* through the mercury U-tube "trap" *S*. The Bourdon tube gauge *T* provides a convenient approximate indication of the pressure existing within the chamber *G*. The air from this chamber may be exhausted through the valve *U*. The screw-operated plunger *V* permits changes in the volume of the air space to be made when it is desirable to change the pressure existing in the chamber *G* by only a small amount. In order to avoid changes in the volume of the air space connected to the chamber *G* when the contact *F* is moved, the upper end of screw *J* is provided with the chamber *N* into which a rod of the same cross section (⅜-in. diameter) as the contact rod *F* is introduced through the packing gland *W*. This device compensates exactly for the change in volume of the air space of the chamber *G* when the contact *F* is moved.

Briefly, the experimental procedure consists in the addition of a known weight of the hydrocarbon mixture to the chamber *C*, which is then brought to the desired temperature. The elevation of the mercury surface in the chamber *G* is determined after equilibrium has been attained and the pressure is established from the reading of the pressure balance after making the necessary corrections of the "heads" of mercury, oil and air in the fluid circuit connecting the pressure balance to the chamber *C*. The quantity of air in the chamber *G* is then changed and a new equilibrium established. This process is repeated throughout the range of total volumes that it is possible to obtain with the size of sample under investigation. The temperature of the cell *C* is then changed and the process repeated. During such time as the apparatus is not in use flow of mercury between the chambers *C* and *G* is prevented by freezing the mercury in the U-tube *Y*, which is an integral part of the connecting tubing.

MEASUREMENT OF PRESSURE

The work of Keyes[1,2,3] and of Beattie and Bridgeman[4] has indicated that the rotating or oscillating piston-cylinder method is perhaps the

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[1] References are at the end of the paper.

most precise convenient means that may be employed for the measurement of elevated pressures. Bridgeman[5] has shown that the vapor pressure of carbon dioxide at the freezing point of water under atmospheric pressure furnishes a satisfactory comparison standard for the evaluation of the "gauge constant" of piston-cylinder pressure measuring instruments. Beattie[6] indicated that this means of calibration is to be preferred to that obtained from the effective geometric dimensions of the piston, unless exceptional precautions are employed. It has been shown[7] that the force exerted by a properly designed and constructed piston-cylinder combination varied directly with the pressure within 0.02 per cent throughout the range from 150 to 8000 lb. per sq. in. A single standardization point is sufficient, therefore, to define the characteristics of a particular piston-cylinder combination within the above-mentioned limits of error. For these reasons it is believed that the use of an absolute instrument to permit the measurements of pressures in terms of primary standards is not necessary for most experimental work. Since calibration of this sort is to be relied upon, the possibility of using an instrument of the balance type becomes available. Such a pressure balance permits the estimation of pressures more rapidly than is possible with the "dead weight" type of instrument. In addition the magnitude of the weights employed with the pressure balance is much smaller and therefore they are more convenient to handle. In designing the instrument here described it was possible to arrange that these weights be added or withdrawn mechanically. The objective in the design of this instrument was, then, the development of a device that exhibited a uniform gauge constant over a wide range of pressures and in which the weights could be added or withdrawn with a minimum of effort or opportunity for mistakes in recording the indications of the instrument.

The general arrangement of the pressure balance is indicated in Fig. 2. The piston-cylinder combination is located at *A*, where it is directly mounted on the cast-iron frame of the instrument. The piston acts downward upon the knife-edge *B*, which is mounted upon the trunnion-supported beam *CC*. This beam is supported within the heavy yoke *D*, which is hung from the stirrup *E*. The details of the stirrup construction are shown in section in a part of Fig. 2. The double knife-edge *F* is mounted in the steel beam *G*. The main knife-edge *H*, which is approximately 3 in. long, is firmly mounted in the beam *G* by means of a brass support in which it was fastened by means of screw-actuated wedges. This main knife-edge bears upon a stellite flat *J*, which is also mounted upon the frame of the instrument. The knife-edges were prepared from tool steel and were hardened, ground and lapped. It is believed that the radius of the knife-edge obtained is less than 0.0003 in. Optical methods were employed in the preparation of the flats and the knife-edges. Extreme care was exercised to insure that the axes of the knife-edges were

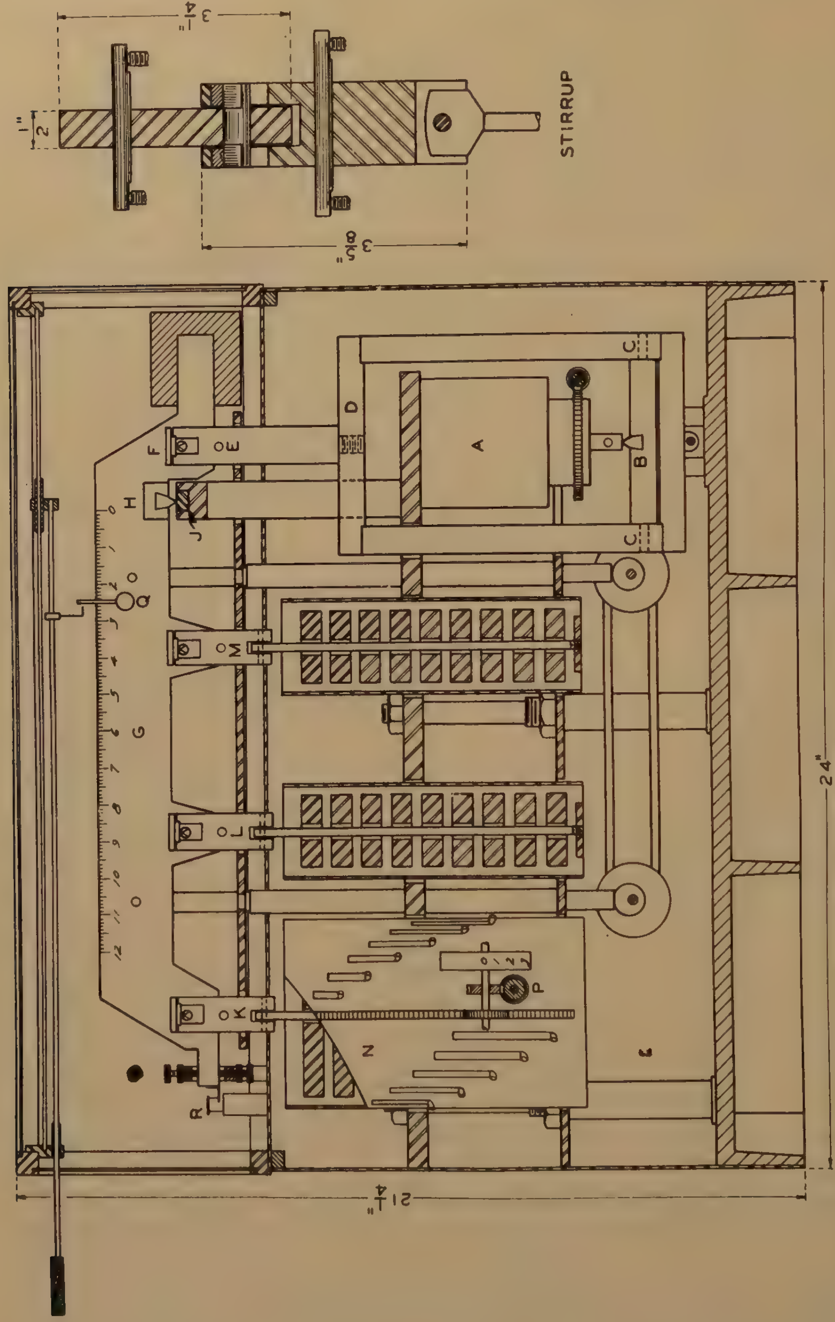

FIG. 2.—CONSTRUCTION OF PRESSURE BALANCE.

parallel to one another and normal to the beam within less than 0.0002 in. at all points. The rotation of the beam about the main knife-edge induced by the action of the piston of assembly *A* is restrained by the three decades of weights *K*, *L* and *M*, respectively. Each decade is supported by a stirrup and double knife-edge similar in all respects to that shown in section in a part of Fig. 2.

The decade *K* is made up of nine weights, each having a nominal value of 1000 lb. per sq. in. These are added or withdrawn mechanically by raising or lowering the weight retainer *N*, which is arranged to pick up the weights from the stirrup *K* successively as the weight retainer is raised from its lowest to its highest position. A counter drum mounted on the spur wheel *P* permits a direct indication of the number of weights on the stirrup *K*. The weights can be simply added or withdrawn by turning a handwheel and the weight on the balance is indicated by a number on the drum, which is read through a small opening in the balance case. The decade *L* consists of nine weights, each having a nominal value of 100 lb. per sq. in., and is controlled in the same manner. The decade *M* is composed of nine weights, each having a nominal value of 10 lb. per sq. in. These also are added or withdrawn by the use of the same type of weight retainer. Changes in weight equivalent to less than 10 lb. per sq. in. are accomplished by the movement of the rider *Q* along the beam *G* in a fashion similar to that employed in the better grade of analytical balances. The beam is so arranged that one inch of movement of the rider corresponds to 1 lb. per sq. in. change in pressure.

The knife-edges in the beam *G* were located relative to one another by means of a cathetometer with an uncertainty of not more than 0.0005 in. It was then necessary only to adjust the weights of each decade to a value consistent with the relative positions of the knife-edges in order to obtain a sequence of forces in the piston that is directly proportional to the nominal values of the weights employed. Each of the weights was adjusted to within 2×10^{-6} lb. of the desired value as compared to brass standards in air. It is believed that these adjustments were made with sufficient accuracy so that no uncertainty greater than 0.008 per cent is introduced from this source. The knife-edges are located on the axis of the beam in order to permit the use of deflection in estimating small changes in pressure.

The beam *G* of Fig. 2 and each of the stirrups *K*, *L* and *M* are provided with lifting mechanisms so that the beam and stirrup can be realigned whenever desired. This mechanism also prevents damage to the knife-edges due to the sudden application of excessive loads. The lifting device was constructed with sufficient rigidity so that only negligible deflections result from the addition of all of the weights to the beam in the arrested position. The piston of the assembly *A* (Fig. 2) is provided with an individual lifting mechanism that can be operated independently of the beam and stirrup arrests. This was done in order to prevent the reaction of the piston on the main lifting mechanism when the balance is subjected to high pressures while not in operation.

The detailed construction of the piston-cylinder assembly is presented in Fig. 3. The piston-cylinder combination used for the actual force measurements is indicated at *A* and *B*. The piston and cylinder were machined from a fine-grained, hardened tool steel and optical methods were employed in finishing them. The conical shape of the exterior surface of the cylinder was employed in order to reduce deformation of the cylinder resulting from variation in pressure along its axis from the interior to the exterior face. This arrangement maintains a rate of oil transfer between the cylinders and pistons, which is nearly directly proportional to the internal pressure and inversely proportional to the viscosity of the oil. The entire inner assembly composed of parts *C*, *D*, *E* and *F* was constructed from chrome-vanadium steel that was heat-treated and ground. The tolerances were maintained below 0.0001 in. throughout and gold-leaf gaskets are employed in sealing the internal chamber *G*. The oil is brought into this chamber through the hollow piston. The piston-cylinder combination *H* and *J* was constructed with the same dimensions and tolerances as those of the main cylinder. In addition, it was so mounted in the holder *K* that it aligns itself with the axis of rotation of the cylinder rather than the geometric axis of the holder *K*. The inner assembly is mounted between two selected preloaded ball bearings and eccentricities of less than 0.0001 in. are encountered in the rotation of the cylinder. No additional forces are applied to the ball bearings because of changes in pressure within the chamber *G*. The upper piston balances the reaction of the lower one on the hanger *D* of Fig. 2. The torque applied to the lower piston is transmitted to this hanger by means of the V-shaped groove in the lower part of the piston. The apex of this groove was constructed with a radius of approximately 0.01 in. The hanger is prevented from rotating by its contact with the double knife-edge *F* of Fig. 2. No tendency for the hanger to rotate is noticed even at pressures below 10 lb. per sq. in. The leakage from the

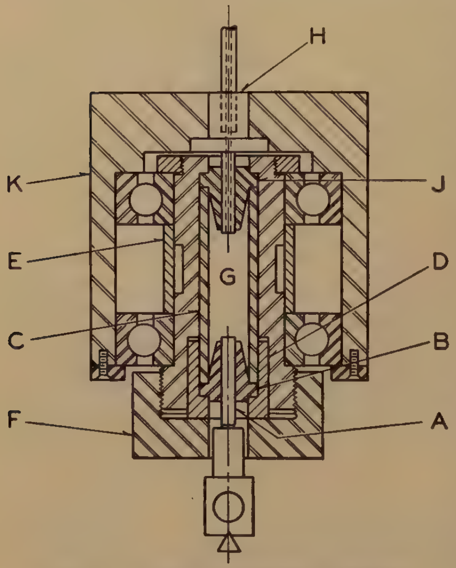

FIG. 3.—PISTON-CYLINDER ASSEMBLY.

piston, when using an oil having an absolute viscosity of approximately 2 centipoises, is 0.01 cu. in. per day at an average pressure of about 3000 lb. per sq. in. The tolerances are somewhat closer than those recommended by Beattie,[6] but no difficulty due to sticking or galling has been experienced. Before entering service the cylinder was rotated around the piston at approximately 30 r.p.m. for over 30 hr. Soy-bean oil was used as a lubricant during this period at a pressure of 2000 lb. per sq. in. The use of this vegetable oil during the working-in period appeared to be desirable when employing such close tolerances as were used in this piston-cylinder combination.

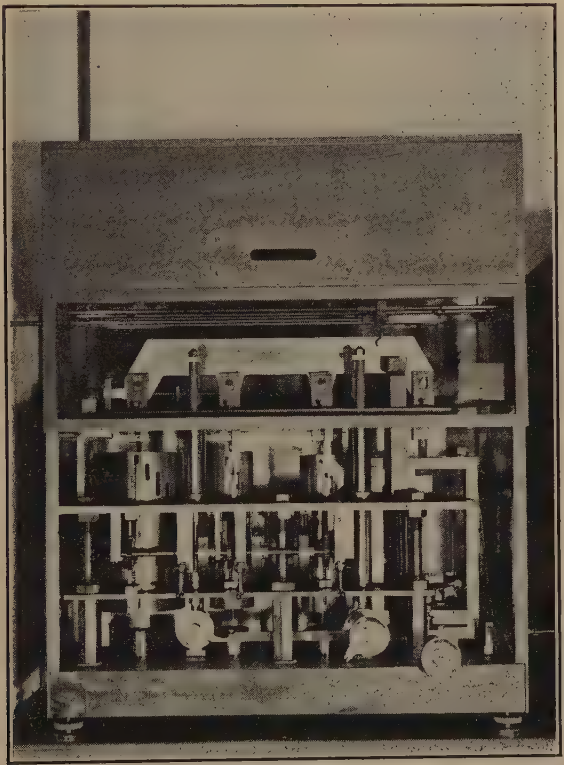

FIG. 4.—PRESSURE BALANCE WITH FRONT COVER PLATE REMOVED.

The use of a second piston-cylinder combination to provide the oil connection to the chamber *G* permits the use of a rotating cylinder rather than the oscillating type that was employed by Keyes.[1] It was found from preliminary work that the reversal of torque on the piston during oscillation tended to induce minor oscillations in the beam assembly. In addition, the hazard of fatigue in the flexible tubing that is often used in balance-type instruments to connect the oscillating cylinder to the other parts of the hydraulic circuit is eliminated.

A photograph of the completed instrument with the front cover plate removed is shown in Fig. 4. The three number-drums, which indicate the weight on the balance, are visible beside the operating handles for manipulating the weights in each of the three decades. The piston assembly and the hanger appear on the right-hand side of the instrument. The box shown above the glass housing for the beam encloses the optical system used in detecting the position of balance of the instrument. A straddle-mounted mirror *R* (Fig. 2) at the left end of the beam is used in conjunction with a compound light beam to magnify the movement of the piston sufficiently so that changes in its position of less than 0.0001 in. may be detected. These small changes coupled with the very small leakage of oil from the piston practically eliminate flow in connecting lines and permit the rapid measurement of pressures with relatively high precision.

In order to compensate for the small leakage of oil from the cylinder and to offset the changes in volume of the oil system due to changes in pressure, a manual screw-operated plunger has been provided, which is indicated at *Z* in Fig. 1. Neoprene packing is employed in this device, and no measurable leakage of oil is encountered at pressures as high as 10,000 lb. per sq. in. The combination of valves shown at D' in Fig. 1 permits the addition of oil to the system from the reservoir E', and also allows the pressure balance to be employed in connection with the measurement of pressure in other parts of the apparatus.

The pressure existing within the air chamber *G* of Fig. 1 at the air-mercury interface is related to the reading of the balance by an equation of the form:

$$P_G = \frac{AS + B + C}{1 - (62 + 0.003N)10^{-6}} \qquad [1]$$

The constant *A** in equation 1 corresponds to the "gauge constant" of the instrument. The gauge constant is assumed to be independent of pressure and there is no need to correct for changes in temperature because of the small variation in room temperature that is encountered in the authors' laboratory. Care is exercised to avoid the rotation of the cylinder for extended periods, since this results in a small rise in temperature of the piston-cylinder combination. The quantity *B* represents the "head" of oil in the tubing connecting the pressure balance with the mercury trap *S* of Fig. 1. The mercury heights in this trap are so adjusted as to be nearly equal; therefore it is not necessary to apply a correction for the change in specific weight of the oil or mercury in the trap *S* due to changes in pressure or room temperature. The neglect of such a correction introduces less than 0.02 lb. per sq. in. uncertainty in the estimation of the pressure. The trap *S* is provided with an electric contact that permits the manual maintenance of the mercury height at a constant value whenever measurements of pressures are made.

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* See nomenclature at the end of the paper.

The term $(62 + 0.003N) \times 10^{-6}$ in equation 1 represents the correction for the head of air between the mercury in the trap S and the mercury surface in the vessel G of Fig. 1. Because of the relatively small magnitude of this term, air is assumed to follow the perfect gas laws and no corrections are made for the minor changes in room temperature (3° F.) permitted during the use of this equipment. It is seen that this term is computed directly from the geometric arrangement of the equipment and the physical properties of air. It is believed, however, that no uncertainty greater than 0.02 lb. per sq. in. could be introduced by the use of these simplifications. The maximum value of this correction is 0.47 lb. per square inch.

The difference in pressure between that at the mercury surface in the air chamber and that at the mercury surface in the working section C of Fig. 1 is established by the following equation:

$$P_G - P = E + 0.001165N \qquad [2]$$

The constant E in equation 2 is independent of temperature, since the changes in height of the mercury in the working section due to changes in temperature compensate exactly for the changes in the density of the mercury. The constant E is determined by connecting a mercury-in-glass manometer to the upper parts of the chambers C and G and measuring the difference in elevation of the mercury in the arms of the manometer as a function of the position of the contact F as determined from the readings of the counter L. This constant may be established in this fashion with an uncertainty of not more than 0.0002 lb. per sq. in. The surface forces associated with the air-mercury interfaces in the chamber G and the trap S result in negligible pressure differences (less than 0.02 lb. per sq. in.) due to the use of relatively large cross-sectional areas.

The pressure in the working section C includes the effect of the presence of mercury in the gas phase of the sample under investigation. It is believed that at temperatures below 600° F. this correction, represented by F in equation 3, may be made with sufficient accuracy by deducting the vapor pressure of mercury (corrected for the effect of pressure) from the total pressure of the system. This follows the procedure adopted by Beattie.[6] On the basis of equations 1 and 2 the pressure exerted by the sample in the working section C may be directly related to the indications of the pressure balance as follows:

$$P = \frac{AS + B + C}{1 - (62 + 0.003N)10^{-6}} - E - 1.165N \times 10^{-3} - F \qquad [3]$$

The constant B and the gauge constant A are the only quantities in this equation requiring evaluation. Two calibration points at known pressures are required to establish these two constants. One point is obtained from the indication of the pressure balance when the working section is filled with carbon dioxide gas at vapor pressure at the ice point. The second is determined from the reading of the balance at a known relatively low pressure in the chamber *C* as determined from the elevations of mercury in the arms of a mercury-in-glass manometer. From the arrangement of the equipment it is possible to establish the vapor pressure of carbon dioxide at a number of total volumes of the system. In addition, the pressure as indicated from the mercury manometer may be established at a number of values of the counter reading *N*. An intercomparison of the values of *A* and *B* as established from these various calibrations indicated a maximum deviation of less than 0.01 per cent.

The carbon dioxide employed for the first calibration was prepared from recrystallized sodium bicarbonate, which was heated in glass at a pressure below 3 in. of mercury. This relatively pure carbon dioxide was dried and further purified by four successive sublimations followed by solidification under reduced pressure at the temperature of liquid air. A repetition of this calibration after intensive use of the instrument for a period of three months indicated that the gauge constant had changed by less than 0.01 per cent. For these reasons it is believed that the magnitude of the pressure within the chamber *C* is established within 0.03 per cent or 0.2 lb. per sq. in., whichever measure of uncertainty is the larger.

Temperature Control and Measurement

The temperature of the room in which the apparatus stands is controlled manually within approximately 3° F. throughout the course of a particular set of measurements. The temperature of the chamber *G* (Fig. 1) is maintained at 120° F. by surrounding it by an agitated oil bath of which the temperature is controlled by means of a mercury-in-glass regulator used in conjunction with a time-delay vacuum-tube relay circuit. The temperature of chamber *G* is measured by the use of a calibrated mercury-in-glass thermometer. The chamber *C* is contained in an agitated oil bath the temperature of which is controlled in a fashion similar to that described by Beattie[6] except that a gas-filled photoelectric cell is employed instead of a selenium cell to control the grid of a Thyratron tube. In general, a maximum current of approximately 0.6 amp. for the half cycle is employed in the 220-volt control circuit, and this varies by less than 0.02 amp. when the bath is substantially at equilibrium. A strain-free platinum resistance thermometer is employed in conjunction with a Mueller-type bridge to actuate the galvanometer light beam that operates the photoelectric cell.

The temperature of the oil bath *B* of Fig. 1 is measured by means of a four-lead, strain-free platinum resistance thermometer. This thermometer was calibrated in place against the readings of a platinum resistance thermometer (Leeds and Northrup No. 8163), which had been recently standardized by the U. S. Bureau of Standards at the oxygen, ice, steam and sulphur points. The ice-point resistance of each thermometer involved in this calibration had changed by less than one part in one hundred thousand after the comparisons at temperatures between 100° and 500° F. The ice point of the measuring thermometer is ascertained each day and any necessary correction is made for the slight variation in this resistance, which amounts to less than two parts in one hundred thousand. It is believed that the temperature of the contents of the cell is known within 0.05° F. relative to the international platinum scale at temperatures between 100° and 520° F. The control circuit maintains the temperature of the oil bath within 0.002° F. of a given value during the course of any one set of measurements.

In order to avoid excessive energy dissipation from the main thermostat bath *B* of Fig. 1, it is surrounded by the steel radiation shield *A*, the inner surface of which is maintained at a temperature only slightly below that of the thermostat *B*. This is accomplished with manually controlled electric heaters wound on the exterior surface of the radiation shield. In general, this shield is maintained at approximately 8° F. below that of the thermostat bath *B*. During operation the current controlled by the Thyratron circuit furnishes all the electrical energy that is added to the main thermostat bath *B*. This procedure avoids large energy transfers in and between various parts of the bath, which would result in unnecessary temperature gradients in the oil body.

The oil within the thermostat bath *B* is agitated by means of two axial-flow propeller-type pumps *D*. These are belt-driven from a vertically mounted motor and are provided with water-cooled ball bearings. The control heaters were star-wound in the outlet of the circulating pumps. They are of low heat capacity, being constructed of 15 ft. of No. 24 Chromel-A ribbon approximately ⅛ in. wide. The top of the thermostat is nearly vaportight, to reduce the oxidation of the oil employed as the thermostat fluid. The three oils used are kept in supply tanks below the thermostat *B* and can be forced into the thermostat tank by compressed air and returned to storage by gravity flow.

Details of Construction

The construction of the bomb and magnetic agitator is shown in the sectional drawing of Fig. 5. The cell itself was constructed from fully annealed stainless steel (18 per cent Cr, 8 per cent Ni) and was machined from a solid billet. The closure is of the unsupported-area type and a copper gasket has been found to function satisfactorily at temperatures up to 500° F. Experience with this equipment indicates that pressures on the gasket in excess of 60,000 lb. per sq. in. are required to induce sufficient plastic flow in the copper gasket to form a perfect closure. The ratio of the supporting area of the gasket to the area of the closure is approximately 0.08. It has been found that this ratio will maintain a perfect seal without stress in the closure bolts except when there are rapid changes in temperatures. For this reason the closure bolts are maintained with a tension of approximately 3000 lb. per bolt, or a total of 18,000 lb. additional force acting upon the gasket. This procedure results in a perfect seal and the closure can be removed without difficulty, since the bolts do not require excessive torque to tighten or loosen. An

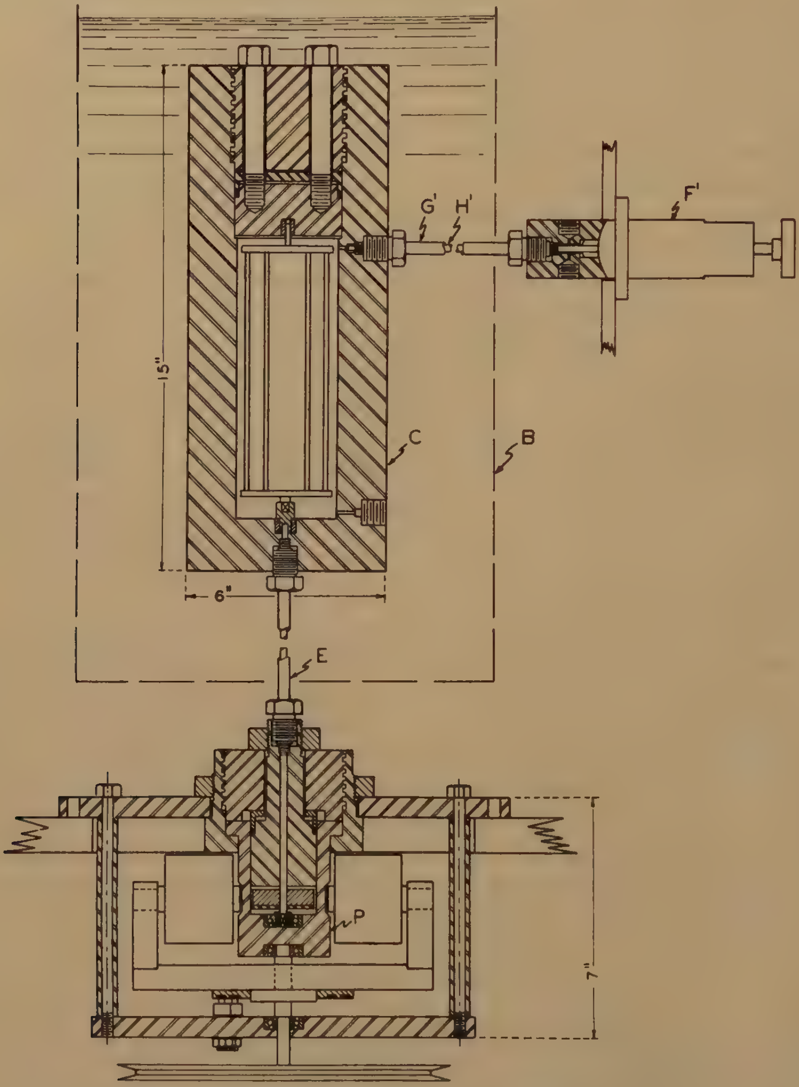

FIG. 5.—WORKING SECTION AND MAGNETIC AGITATOR.

attempt was made to employ pure iron gaskets in the closure. However, because of the large increase in the ultimate unit tensile strength of this material with an increase in temperature below 400° F., it was impossible to obtain satisfactory seals at higher temperatures without unduly deforming the cell itself.

The nonmagnetic shell within which the armature of the magnetic device is confined is made of completely annealed steel containing 18 per cent Cr and 8 per cent Ni. This material exhibits a very low permeability and permits the transmission of approximately 2 in.-lb. of torque using an electromagnet composed of two coils of No. 30 wire of approximately 3600 turns each with a direct current of approximately 0.5 amp. The remaining parts of the magnetic circuit were constructed of Armco iron and the air gaps were maintained below 0.003 in. In order to avoid significant errors from the expansion of the mercury in the agitator housing, due to minor changes in the temperature, the entire equipment was designed so as to leave as small a volume as possible to be occupied by mercury. The entire magnetic agitator *P* (Fig. 5) and the connecting tube *E* contain less than 0.5 cu. in. of mercury. The changes in room temperature that are permitted result in less than 0.0002 cu. in. change in volume of the mercury in the system. The electromagnet is rotated by means of a belt drive at approximately 100 r.p.m. and the current is supplied to the coils through brass slip rings employing carbon brushes. The agitator is provided with a ball bearing in the bottom of the nonmagnetic shell and with graphitic cast-iron bushings at the bottom and top of the chamber *C* of Fig. 5. A square slip joint is provided between the drive shaft within the tube *E* and the agitator itself. This permits the removal of the agitator for adequate cleaning of the interior walls of the cell when the closure is removed.

The cell was designed to have less than 0.01 per cent change in volume per 1000 hr. of service due to creep at a temperature of 900° F. and at an operating pressure of 9000 lb. per sq. in. Under these circumstances, it is believed that the hysteresis of this part of the apparatus will be negligible under most of the conditions of operation anticipated. All parts of the equipment exposed to mercury were constructed of annealed stainless steel, which apparently resists significant amalgamation at 600° F. and pressures in excess of 5000 lb. per square inch.

The arrangement of the chamber *G* of Fig. 1 with its movable contact is shown in the sectional drawing of Fig. 6. The chamber was constructed from a billet of annealed stainless steel (18 per cent Cr, 8 per cent Ni) and was provided with an unsupported area closure using a Neoprene gasket. In this instance the supporting area of the gasket is approximately 18 per cent of the area of the closure. No stress in the closure bolt is required in order to induce a perfect seal. A combination of Neoprene and leather packing is employed in the gland where the movable contact *F* enters the chamber *G*. The packing nut is provided with a gear and worm *S* to permit the rapid and easy adjustment of the packing gland. Since this was immersed in the oil bath, a sprocket and chain drive connects the packing adjustment screw to a handwheel on the operating table.

The entire assembly is supported from a framework upon which the operating table rests. The screw *J* has a square thread of 12 pitch and engages the steel nut *T*, which is mounted between preloaded ball bearings as indicated in the figure. The worm driving this nut through a worm gear is also mounted between preloaded ball bearings and is connected to a counter that indicates the location of the contact point *F*. A similar type of packing gland provided with a worm-wheel adjustment is employed for the compensator *N*. It was found to be unnecessary to thermostat this compensator because of its small volume and the relatively small variation in room temperature that is permitted. The apparatus is so arranged that one revolution of the worm *M* corresponds to a movement of the contact of 0.00119 in. In general, the measurement of the elevation of the mercury surface can be reproduced within 0.2 revolution of the worm *M*, which is equivalent to a movement of 0.00024 in. Since the vessels *C* and *G* (Fig. 1) are of the same cross section within small limits, an accuracy of volume indication within 0.03 per cent can be obtained as long as the sample occupies a length of more than 1 in. in the upper part of the chamber *C*. A vacuum-tube relay *A′* (Fig. 1) using a current of about 3 microamperes

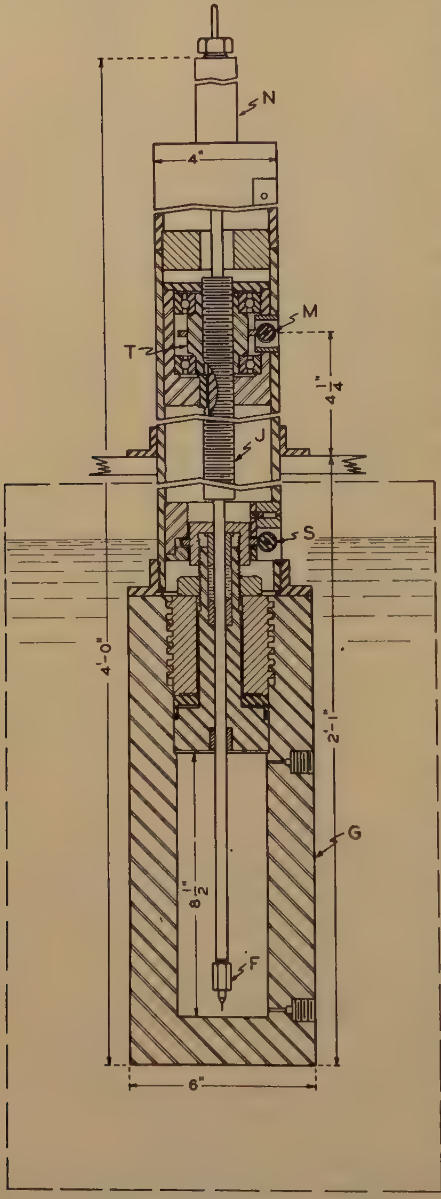

FIG. 6.—AIR CHAMBER AND ELECTRICAL CONTACT ASSEMBLY.

at 200 volts was employed in connection with the contact *F*. This vacuum-tube relay circuit when completed by contact between the point *F* and the mercury surface in the chamber *G* actuates a signal light, which is thus used in determining the elevation of the surface.

The valves used for the admission of the sample to the chamber *C* and for the control of the air admitted or released from the chamber *G* were constructed as indicated in sectional view in Fig. 7. This design is somewhat complicated, but permits movement of the valve stem only parallel to its axis. This elimination of rotary movement reduces the wear on the packing to a marked extent and also avoids galling of the valve point and seat. In these valves a Monel point bearing upon a steel seat is employed and no difficulty is encountered in obtaining a perfect closure throughout a large number of operations of the valve. For valves that are not opened, or closed under pressure, the conventional high-pressure valve design using Neoprene packing is employed. However, these were all specially constructed to rather close tolerances from bar-steel stock.

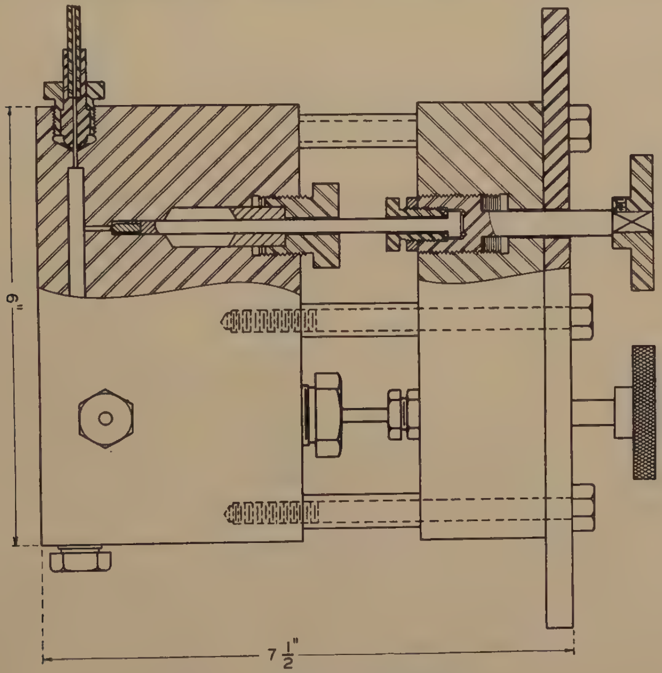

FIG. 7.—AIR-CONTROL VALVES.

MEASUREMENT OF VOLUME

Apparatus of this nature requires rather extensive calibrations in order to interpret the readings of the counter *L* of Fig. 1 in terms of the effective volume of the chamber C. First the counter reading is determined as a function of the weight of mercury withdrawn from the chamber G. The results of this calibration have indicated that the relationship is linear within 0.01 lb. of mercury in a total weight of about 20 lb. These small deviations $\underset{\sim}{\mathrm{W}}$ are taken into account by residual graphical methods and are applied in all of the calculations of the experimental results from this apparatus. For the most part, the experimental points deviate by less than 0.0002 lb. from the smoothed relationship of weight to counter reading. This calibration is carried out at a pressure only slightly above that of the atmosphere.

Next, the mercury in the connecting tubing is frozen and the change in counter reading with respect to pressure is determined for a number of positions of the mercury surface. From these measurements combined with the previous data the weight of mercury removed from the chamber between any two counter readings can be established from a relationship of the following form:

$$\Delta W = W_1 - W_2 = 0.00410900[N_1 - N_2 - (2.67 - 0.00040N_1)P_1 \times 10^{-3} + (2.67 - 0.00040N_2)P_2 \times 10^{-3}] + \underset{\sim}{\mathrm{W}}_1 - \mathrm{W}_2 \quad [4]$$

Numerous calibrations indicate that equation 3 describes the change in weight of the mercury within chamber G within 0.0001 pound.

The chamber C is then filled completely with mercury and the change in counter reading is determined as a function of pressure and temperature. This is recorded by residual methods and represents the effect of pressure and temperature upon the volume of chamber C with its connecting tubing both as a function of pressure and temperature.

From this information it is possible to evaluate the weight of mercury corresponding to the volume of the hydrocarbon sample under the conditions in question. The quantity is obtained directly from the calibration of the chamber G and the difference in the counter readings between those obtained when the chamber C is filled with mercury and those obtained when a sample of known weight is placed within it. The measurements by Smith and Keyes[8] are employed to evaluate the effect of pressure upon the specific volume of mercury. The specific volume of mercury at atmospheric pressure as a function of temperature is taken from an accepted formulation.[9] It is believed that the calibrations can be carried out with sufficient precision that no uncertainties in the weight of mercury corresponding to the volume occupied by the hydrocarbon sample greater than 0.0005 lb. are involved. The specific volume of mercury is probably known within 0.05 per cent throughout the range of pressures and temperatures involved in this investigation.

In addition, it is necessary to correct for the weight of mercury in the space occupied by the sample. For gases the correction is made in accordance with the method outlined by Beattie.[10] However, this correction may be neglected at temperatures below 400° F. For these reasons, it is believed that the total volume of the hydrocarbon sample may be established within 0.07 per cent as long as it occupies more than 20 per cent of the total working volume of the chamber *C* of Fig. 1.

WEIGHT OF SAMPLE

All the samples are added to the working section through the valve *F′* of Fig. 1. This valve is of the axial movement type and the seat is an integral part of the pressure vessel *C*, as is indicated in Fig. 5. The point is made of hard-drawn Monel metal and no difficulty with amalgamation has as yet been experienced. Care was exercised to employ the same type of steel in the tube *G′* and the stem in order to avoid changes in bearing pressure on the valve seat due to changes in temperature of the chamber *C*.

Noncondensable gases such as methane are added to the working section from the isothermal, isochoric chamber *K′* of Fig. 1. This chamber is made of stainless steel and is provided with an unsupported area closure similar to that shown in Fig. 5. The pressure within this chamber is measured by means of the pressure balance, which is connected to it through the valve assembly *D′* shown in Fig. 1. Contact of the oil in the connecting tubing with the gas in the chamber *K′* is prevented by the mercury in the chamber *L′*, which is mounted outside the thermostat bath enclosing the chamber *K′*. The chamber *L′* is provided with an electric contact in order that the mercury level may be maintained at a constant position by means of the manually operated plunger *Z*. The chamber *K′* is maintained within 0.005° F. of the desired temperature (120° F.) by means of a mercury-in-glass regulator controlling a vacuum-tube relay circuit in the conventional fashion. The inlet valve forms an integral part of the closure, thereby reducing the need for additional fittings in the calibrated part of the system. The tubing connecting the chamber *K′* with the chamber *C* through the valve *M′* is maintained at a uniform temperature by the circulation of oil around it from the oil bath *N′*, by means of the gear pump *O′*. The isochoric chamber *K′* is calibrated by filling it with the gas to be measured and withdrawing quantities of this gas into the chamber *C*, where the volume is measured under conditions for which pressure-volume-temperature properties are known. From a series of measurements of this nature, it is possible to determine the weight of gas withdrawn from the chamber *K′* into the chamber *C* as a function of the change in pressure in the chamber *K′*. It should be realized that the tubing between this chamber and the valve *M′* as well as the tube *G′* and a part of the valve body *F′* form parts of the isochoric system. These were all maintained at a constant temperature by the circulation of oil from the thermostat *N′*. It is believed that this method of measurement of the quantity of noncondensable

sable gases added to the chamber C involves no uncertainties greater than 0.06 per cent as long as the change in pressure within the vessel K' is greater than 200 lb. per square inch.

Easily condensable materials such as ethane, pentane or heptane are added from small weighing bombs through the valve F' in Fig. 1 by means of an auxiliary connection not shown. The weighing bombs used are shown in Fig. 8. The type depicted in part A is constructed of chrome-molybdenum steel and the ends are sweated and screwed to the main body of the bomb. The valve employed is of the conventional packed type and employs a Monel metal point. Bombs of this type are used for the more difficultly condensable materials, which can be adequately removed by evacuation. These bombs have a working pressure of approximately 1000 lb. per square inch. The type shown in part B of Fig. 8 is constructed of steel containing 1 per cent C, 18 per cent Cr, and 8 per cent Ni. It consists of two parts, which are connected by an unsupported area seal. The valves are of the diaphragm type and are arranged to permit purging of the closed valve. This latter form of construction is especially desirable in connection with the addition of relatively nonvolatile materials.

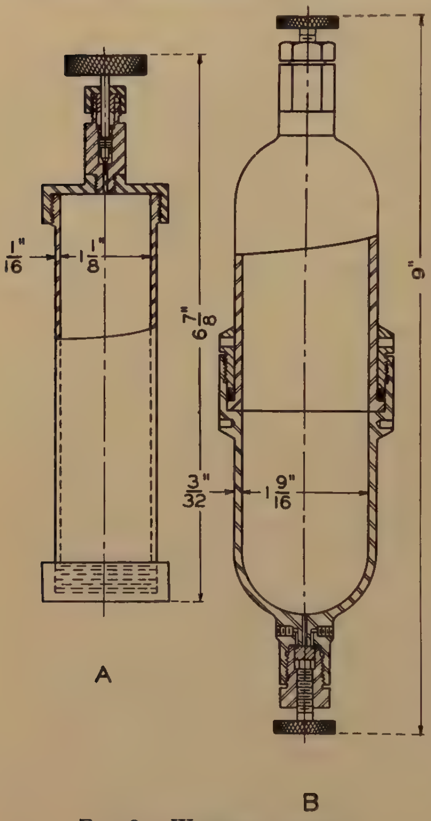

Fig. 8.—Weighing bombs.

The bombs are baked, evacuated and filled with the desired hydrocarbon. The chamber C (Fig. 1) is also evacuated by means of the mercury diffusion pump P' which is connected to the valve F' through the valve R'. The McLeod gauge T' provides the necessary indication of the pressure existing within the chamber C. This chamber is evacuated for a period of at least 6 hr. at a temperature higher than the maximum to be employed in the investigation, in order to remove adsorbed gases from the steel walls.

The weighing bomb is weighed using a nearly identical tare. The hydrocarbon is distilled into the chamber C, the valve F' is closed, and the residual gas in the tube G' is recondensed into the weighing bomb by means of liquid air. The weight of the weighing bomb is again determined by substitution weighing, and appropriate air-buoyancy corrections for the stainless-steel weights employed are applied. Upon completion of a series of measurements the sample of hydrocarbon is again withdrawn and its weight determined. A comparison of the results

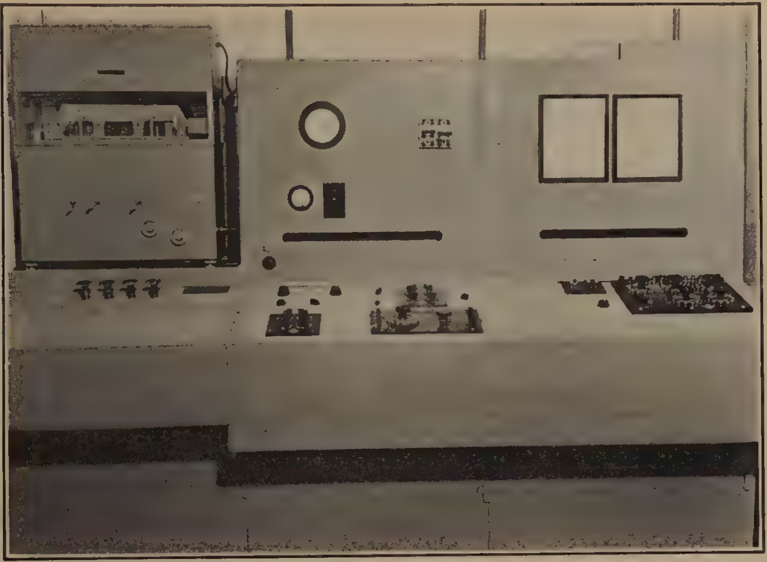

FIG. 9.—ARRANGEMENT OF APPARATUS FOR CONTROL AND MEASUREMENT OF TEMPERATURE AND PRESSURE.

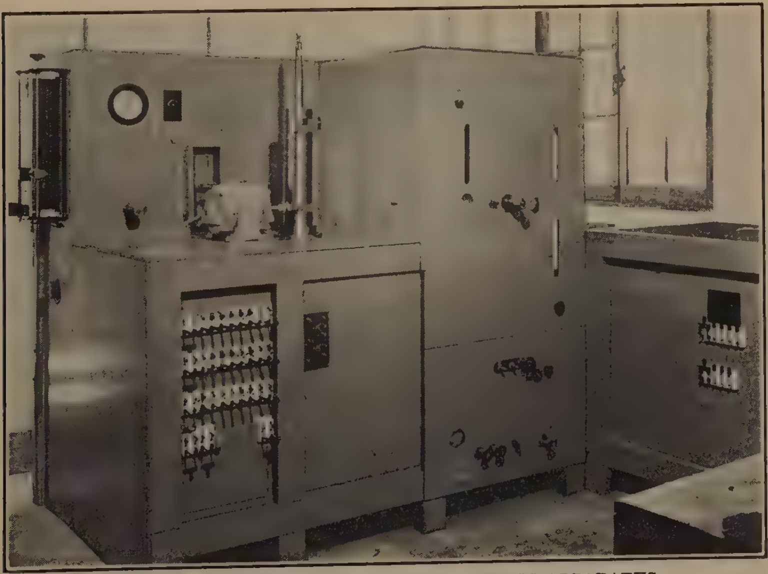

FIG. 10.—GENERAL VIEW OF VOLUMETRIC APPARATUS.

obtained from these two measurements has indicated that the weight of a condensable hydrocarbon added to the chamber C may be determined within 2.2×10^{-6} pounds.

The absolute uncertainty of the measured specific volume of hydrocarbon mixtures as a function of pressure, temperature and composition appears to be about twice that predicted from the uncertainty of the individual determinations of pressure, temperature, volume and weight of each component. These discrepancies may be ascribed in part to the occlusion of small parts of the sample beneath the mercury within the chamber C due to preferential wetting of the walls. Also, the gradual creep of the chamber C introduces an element of uncertainty that is difficult to overcome. For these reasons it is believed that the over-all uncertainty of measurement will vary from 0.1 per cent at the lower temperatures to as large as 0.25 per cent at temperatures in excess of 460° F.

ARRANGEMENT OF APPARATUS

A photograph of the control bench is presented in Fig. 9. The pressure balance is on the left-hand end of the bench and the oil-control valves (D' of Fig. 1) in the pressure-measuring system have been placed just below the balance. The bridge used in conjunction with the resistance thermometer for temperature regulation is in the central part of the control bench. Above this is a Bourdon-tube pressure gauge T, used as a rough indication of the pressure existing within the oil-filled pressure-measuring circuit. The small potentiometer at the right of the control bridge is used in measuring the temperature gradient between the radiation shield and the high-temperature thermostat bath which it surrounds. It is also useful in establishing the magnitude of the temperature gradients in the tubing connections to the main working section. The Mueller-type bridge with the commutator is at the extreme right of the control bench. The galvanometers are behind the bench and a series of mirrors is employed to permit the use of relatively long light beams (10 ft.) in the rather small space available. The scales for the galvanometers are directly above the potentiometer and Mueller-type bridge within the slots in the panel.

A general view of the volumetric apparatus is presented in Fig. 10. The motor-driven movable contact for determining the elevation of the mercury surface in the air chamber is in the central part of the equipment. The high-temperature thermostat bath is to the right of the movable contact and is completely inclosed. The outlet of the sample-addition valve has been placed on the front panel so as to be readily accessible. The valves shown on the lower right-hand part of the apparatus are used for the addition or withdrawal of oil from the thermostat and for the control of cooling water to bearings and to a mercury diffusion pump.

The valves just below the movable contact are used for the addition or withdrawal of air from the air chamber. The isochoric chamber K' of Fig. 1 is housed in a thermostat bath behind the panel on the right of Fig. 10.

ACKNOWLEDGMENTS

This apparatus was constructed in the Laboratory of Chemical Engineering of the California Institute of Technology, through the financial assistance of the Union Oil Company of California and the Polymerization Process Corporation. Donald Emberson, Willard DeWitt and Samuel Weaver assisted with the machine design and instrument work. William Morris and Hollis Reamer assisted materially in the installation, testing and operation of this equipment.

NOMENCLATURE

A, gauge constant.
B, additive constant involved in calibration of pressure balance, lb. per sq. in.
C, barometric pressure, lb. per sq. in.
E, additive constant involved in the calculation of pressure in the working section, lb. per sq. in.
F, additive correction for vapor pressure of mercury, lb. per sq. in.
N, reading of counter L of Fig. 1.
P, pressure in working section, lb. per sq. in.
P_a, pressure in air chamber, lb. per sq. in.
S, pressure balance reading.
W, weight of mercury in air chamber, lb.
$\underset{\sim}{W}$, correction to weight of mercury in air chamber for geometric irregularities, lb.

REFERENCES

1. Keyes: *Proc.* Amer. Acad. Arts and Sci. (1933) **68,** 505.
2. Keyes and Brownlee: Thermodynamic Properties of Ammonia. New York, 1916. John Wiley and Sons.
3. Keyes and Dewey: *Jnl.* Optical Soc. Amer. (1927) **14,** 491.
4. Beattie and Bridgeman: *Ann. Pysik.* (1932) [5] **12,** 827.
5. Bridgeman: *Jnl.* Amer. Chem. Soc. (1927) **49,** 1174.
6. Beattie: *Proc.* Amer. Acad. Arts and Sci. (1934) **69,** 389.
7. Beattie and Edel: *Ann. Pysik.* (1931) [5] **11,** 633.
8. Smith and Keyes: *Proc.* Amer. Acad. Arts and Sci. (1934) **69,** 285.
9. International Critical Tables, II, 457. New York, 1927. McGraw-Hill Book Co.
10. Beattie: *Proc.* Amer. Acad. Arts and Sci. (1934) **69,** 389.

Volumetric Behavior of Isobutane

By W. M. Morris,* B. H. Sage,* Member A.I.M.E., and W. N. Lacey*

(Los Angeles Meeting, October 1939)

The volumetric behavior of isobutane at temperatures below its critical temperature has been studied by several investigators. Seibert and Burrell[1] measured the vapor pressure of isobutane from the ice point to the critical temperature. Dana and co-workers[2] determined among other thermodynamic quantities the density of the saturated liquid and the saturated gas and the vapor pressure from approximately 0° to 130° F. Sage and Lacey[3] studied a number of the thermodynamic properties of this hydrocarbon from 70° to 250° F. The specific volume in the gas and liquid region was determined at pressures up to 3000 lb. per sq. in.† throughout this temperature interval. In addition, the vapor pressures were measured at 30° intervals. These data taken together serve to establish the thermodynamic behavior of isobutane at temperatures between 0° and 250° F. with reasonable accuracy. However, apparently there are no data available at the higher temperatures. For this reason an investigation of the volumetric behavior of isobutane at temperatures between 100° and 460° F. was carried out with apparatus that has been described in another paper (p. 136, this volume).

MATERIALS

The isobutane used in this investigation was obtained from the Philgas Division of the Phillips Petroleum Co. That company's special analysis upon this sample indicated it to contain less than 0.03 mol per cent of impurities. In order to avoid traces of noncondensable gases, this hydrocarbon material was subjected to two successive fractionations at a high reflux ratio in a column approximately 4 ft. long and ½ in. in diameter, which was packed with small glass rings. The middle portion of distillate from the first fractionation was used in the second fractionation and a portion of the overhead from this second distillation process was repeatedly condensed at liquid-air temperatures at a pressure only slightly above the sublimation pressure of isobutane at this temperature.

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* California Institute of Technology, Pasadena, California.

[1] References are given at the end of the paper.

† All pressures reported in this paper are absolute.

The material used in the volumetric studies showed a change in vapor pressure of approximately 0.2 lb. per sq. in. during the course of an isothermal condensation at 220° F.

RESULTS

Three samples of isobutane were studied in the course of this investigation. In each case the weight of isobutane employed was checked by the withdrawal of the sample from the apparatus upon the completion of the experimental measurements. These additional data indicated that the weight of hydrocarbon involved was known within 0.02 per cent for each of the samples investigated. A calibration of the apparatus was made before and after the investigation of each sample and the fluid-pressure balance was calibrated before and after the experimental program. The latter calibration indicated an accuracy of pressure measurement of 0.05 per cent at pressures above 500 lb. per square inch.

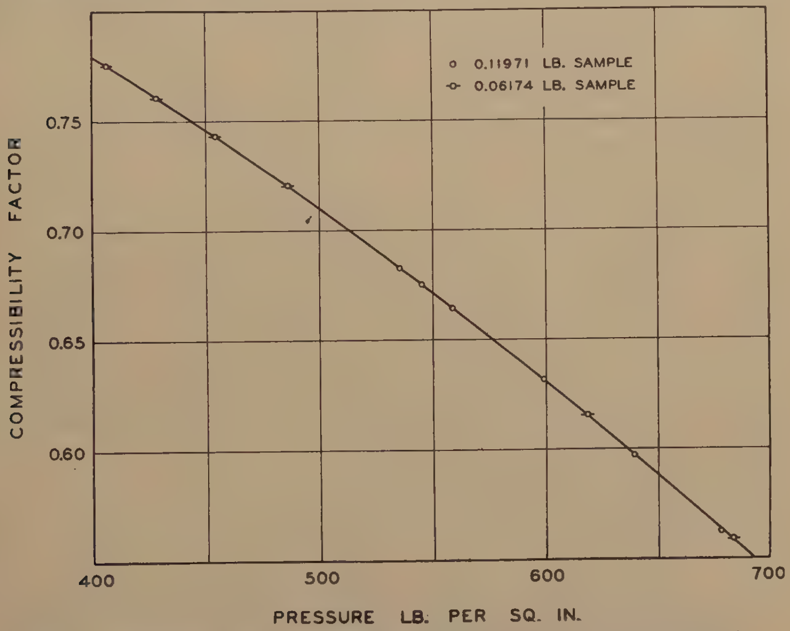

FIG. 1.—RESULTS FOR TWO SAMPLES OVER SHORT PRESSURE INTERVAL.

In order to illustrate the precision of measurement obtained, the results for two of the samples at 340° F. over a short pressure interval are presented on an enlarged scale in Fig. 1. The compressibility factor—i.e., the ratio of the actual specific volume to that predicted from the perfect gas law—has been employed as a coordinate in the diagram in order to show the volumetric data with greater graphical accuracy than would be possible if specific volume were plotted in a diagram of the same size. The diameter of the circles indicating each of the experimental points corresponds to a change in specific volume of approximately 0.1 per cent. It should be realized that this temperature is only about 70° F. above the critical temperature of isobutane, therefore small changes in pressure result in rather marked changes in specific volume. In general, the agreement of the data for the two samples is good and indicates a satisfactory precision of measurement.

All of the experimental points at temperatures of 280° F. and higher are shown in Fig. 2. The compressibility factor is presented as a function of pressure for the several temperatures investigated experimentally. At pressures in the neighborhood of 700 lb. per sq. in. at 280° F., the actual volume of isobutane is only about 20 per cent of that predicted from the perfect gas law. However, at pressures above 4500 lb. per sq. in. the specific volume of isobutane is greater than that predicted from the perfect gas relationship. The experimental points shown on this diagram indicate the scope and detail of the experimental work carried out in this temperature range.

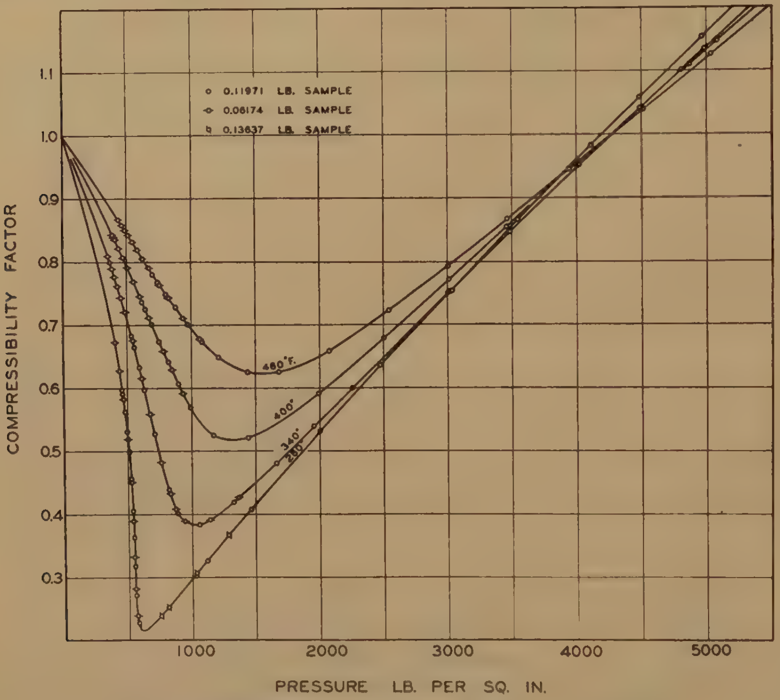

FIG. 2.—EXPERIMENTAL POINTS AT 280° F. AND ABOVE.

The specific volume of liquid isobutane at temperatures below that of the critical state is presented as a function of pressure in Fig. 3. The data for 280° F. at the higher pressures are included for comparison. The experimental points for the two largest samples investigated have been included. The present work was directed toward an investigation of isobutane at temperatures above its critical temperature. Therefore these data at the lower temperatures are not as accurate as those at the higher temperatures, the total volumes of the samples investigated being insufficient under these conditions to permit measurement with the highest accuracy.

The experimental results were plotted on a large scale, which permitted interpolation with an accuracy comparable with the precision of measurement, and the specific volumes at even values of pressure were established. These have been recorded in Table 1 for each of the temperatures investigated experimentally. No experimental work was carried out at pressures below 300 lb. per sq. in., and the values for the lower pressures were extrapolated toward unity upon a large-scale diagram similar to Fig. 2. It is believed that the pressure and temperature of measurement and the weights and volumes of the samples were established with sufficient accuracy so that no uncertainty greater than 0.3 per cent is involved in the tabulated specific volumes in the gaseous region. In general, the individual experimental points at the higher temperatures agree with the smoothed values with a maximum error less than 0.08 per cent. The specific volume over a narrow range of pressure in the vicinity of the critical pressure of isobutane is recorded for 280° F. in Table 2. These data have been included in order to present

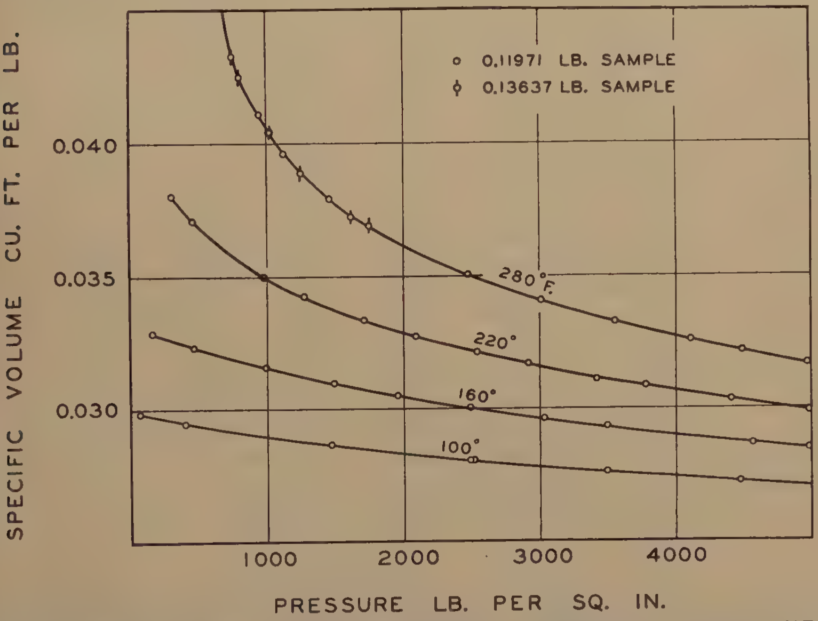

FIG. 3.—SPECIFIC VOLUME OF LIQUID ISOBUTANE AT TEMPERATURES BELOW THAT OF CRITICAL STATE AS FUNCTION OF PRESSURE.

TABLE 1.—*Specific Volume of Isobutane*

Pressure, Lb. per Sq. In.	100° F.	160° F.	220° F.	280° F.	340° F.	400° F.	460° F.
Saturated liquid	0.02981[a]	0.03284	0.03799				
100	0.02978			1.272	1.403	1.522	1.642
200	0.02969	0.03277		0.5857	0.6634	0.7299	0.7952
400	0.02950	0.03236	0.03746	0.2306	0.2874	0.3322	0.3718
500				0.1437	0.2091	0.2514	0.2866
600	0.02932	0.03202	0.03640	0.049	0.1547	0.1971	0.2297
700				0.0446	0.1136	0.1584	0.1890
800	0.02916	0.03170	0.03559	0.04245	0.08350	0.1290	0.1589
900					0.06494	0.1067	0.1357
1000	0.02900	0.03141	0.03495	0.04079	0.05645	0.08994	0.1176
1250	0.02881	0.03108	0.03429	0.03884	0.04780	0.06574	0.08731
1500	0.02864	0.03079	0.03374	0.03779	0.04411	0.05551	0.07045
1750	0.02848	0.03053	0.03327	0.03688	0.04197	0.05019	0.06084
2000	0.02833	0.03028	0.03286	0.03613	0.04041	0.04698	0.05510
2250	0.02819	0.03006	0.03249	0.03550	0.03920	0.04471	0.05134
2500	0.02807	0.02986	0.03216	0.03496	0.03824	0.04301	0.04856
2750	0.02794	0.02966	0.03186	0.03449	0.03744	0.04167	0.04649
3000	0.02782	0.02948	0.03159	0.03406	0.03682	0.04060	0.04481
3250	0.02771	0.02932	0.03133	0.03368	0.03628	0.03979	0.04343
3500	0.02760	0.02917	0.03109	0.03332	0.03577	0.03904	0.04227
3750	0.02749	0.02903	0.03087	0.03299	0.03533	0.03842	0.04131
4000	0.02739	0.02889	0.03066	0.03269	0.03490	0.03780	0.04047
4250	0.02729	0.02876	0.03045	0.03240	0.03450	0.03723	0.03972
4500	0.02720	0.02863	0.03026	0.03213	0.03416	0.03671	0.03904
4750	0.02711	0.02852	0.03008	0.03188	0.03384	0.03627	0.03846
5000	0.02703	0.02841	0.02991	0.03164	0.03353	0.03590	0.03795

[a] Specific volume, cubic foot per pound.

TABLE 2.—*Specific Volume of Isobutane at* 280° *F.*

Pressure, Lb. per Sq. In.	Specific Volume, Cu. Ft. per Lb.	Pressure, Lb. per Sq. In.	Specific Volume, Cu. Ft. per Lb.
460	0.1770	550	0.0836
480	0.1602	560	0.0595
500	0.1437	570	0.0551
520	0.1255	580	0.0518
530	0.1152	600	0.049
540	0.1023	700	0.0446

the volumetric behavior at this temperature in greater detail than is possible from information recorded in Table 1.

The present data do not overlap other published information in the gaseous region. Temperature interpolation indicates a satisfactory degree of agreement between the earlier measurements by Sage and Lacey and the present data. There is some indication that the Joule-Thomson data employed in establishing the behavior of isobutane at pressures in the neighborhood of 100 lb. per sq. in. yielded values of the specific volume at 250° F. that disagree with the present data by as much as 0.4 per cent. However, for the most part the two sets of data do not disagree by more than 0.2 per cent in the gaseous region.

In Table 3 is presented a comparison of the specific volume of liquid isobutane as determined by several investigators. The agreement is satisfactory but the present data indicate a slightly smaller isothermal compressibility than would have been predicted from the earlier measurements by Sage and Lacey. The agreement at low pressures is in general much better than the accuracy of measurement involved in the two sets of data and is probably fortuitous.

TABLE 3.—*Comparison of Values for Specific Volume of Liquid Isobutane*

Temperature, Deg. F.	Pressure, Lb. per Sq. In.	Dana	Sage and Lacey	Authors
100	Sat. liq.	0.02990[a]	0.02981	0.02981
	1000		0.02900	0.02899
	2000		0.02831	0.02833
	3000		0.02776	0.02782
160	Sat. liq.		0.03285	0.03284
	1000		0.03139	0.03141
	2000		0.03027	0.03028
	3000		0.02944	0.02948
220	Sat. liq.		0.03799	0.03799
	1000		0.03484	0.03495
	2000		0.03278	0.03286
	3000		0.03152	0.03159

[a] Specific volume, cubic foot per pound.

The vapor pressures of isobutane recorded at two temperatures in Table 1 are compared with data interpolated from the measurements by other investigators in Table 4. This comparison indicates that the present measurements are in fair agreement with Dana's data and the earlier measurements by Sage and Lacey. However, the measurements by Seibert and Burrell are markedly higher than those of the other observers.

TABLE 4.—*Comparison of Values for Vapor Pressure of Isobutane*

Temperature, Deg. F.	Siebert and Burrell	Dana et al.	Sage and Lacey	Authors
160	171.9	162.9	161.1	161.4
220	324.9		313.7	312.8

ACKNOWLEDGMENTS

The authors are indebted to the Polymerization Process Corporation for financial assistance in the prosecution of this work. Hollis Reamer assisted with many of the measurements reported.

REFERENCES

1. Seibert and Burrell: *Jnl.* Amer. Chem. Soc. (1915) **37**, 2683.
2. Dana, Jenkins, Burdick and Timm: *Refrig. Eng.* (1926) **12**, 387.
3. Sage and Lacey: *Ind. and Eng. Chem.* (1938) **30**, 673.

Effect of Temperature on Plastering Properties and Viscosity of Rotary Drilling Muds

By H. T. Byck*

(Galveston Meeting and Los Angeles Meeting, October 1939)

The plastering properties of six representative California drilling muds were studied over a temperature range of 70° to 175° F. at several mud weights, using a high-pressure circulating filter press with full size consolidated cores. In all tests, with untreated as well as with chemically treated muds, the filtration rates at elevated temperature were higher than at low temperatures and in nearly every case this increased filtration rate was notably larger than could be attributed alone to the decreased viscosity of water—the flowing medium—at elevated temperatures.

It is concluded that no existing method will permit even an approximate determination of the filtration rate at high temperature from data at room temperature. It is necessary to measure filtration at the temperature actually anticipated in the well, or to make a sufficient number of tests at various lower temperatures so that a small extrapolation of these data to the anticipated well temperature may be applied. Such tests should be carried out on the mud as actually used in the well.

The viscosity of each of the muds was determined over the same temperature range. While no relationship was observed between mud viscosity and plastering properties, it was found that chemical treatment of the muds for viscosity reduction shifted the temperature of minimum viscosity to appreciably higher values than for untreated muds.

Importance of Plastering Properties

A survey of the literature on rotary drilling muds clearly shows the growing realization of the importance of plastering properties,[1–5] not only from the point of view of the successful completion of the mechanical operation of drilling the well but also from the point of view of minimum impairment of the natural flow possibilities of a given well.

Poor plastering properties with attendant high filtration rate (large water loss to the formation) and thick mud sheath, lead to stuck drill

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* Shell Development Co., Emeryville, California.

[1] References are at the end of the paper.

pipe, difficulty in landing casing, etc., and may promote certain types of heaving when the water filters into bentonitic and related formations. Furthermore, the penetration of water together with fine colloidal matter into the oil-bearing sand may have a marked influence upon the rate of subsequent production of oil from that sand.

EFFECT OF ELEVATED TEMPERATURE

It is to be expected that elevated temperature will alter the plastering properties of a mud, since, among other factors, the viscosity of water is diminished by increased temperature. If all other properties of the mud fluid and filter cake remained unchanged, this decrease in viscosity of water, the flowing medium in filtration, should cause an impairment in plastering directly related to its change in viscosity. In addition, however, accelerated flocculation[4] at elevated temperatures should contribute to the impairment in plastering properties, through alteration in the physical structure and compressibility of the mud sheath leading to altered permeability of the sheath. Furthermore, the effect upon plastering of the known viscosity-reducing agents may be expected to vary with temperature.

Experimental Work

The experimental data were obtained on a large mudding-off machine patterned after the Jones and Babson[1] circulating filter press, in which, however, cylindrical consolidated cores, 3 in. in diameter by 3 in., rather than unconsolidated compacted sands, were exposed to continuously circulating mud fluid at a pressure representing an average bottom-hole pressure differential, and at various temperatures in the range 70° to 175° F. It is generally agreed that unconsolidated sands behave differently from consolidated sands, but much of the work so far published has been with the former.

It is not the intention of this paper to discuss the relative merits of various types of mud-testing equipment, nor to enter into a discussion of the advantages of testing with or without mud circulation. It is believed, however, that conditions more nearly representing field practice are obtained when circulation is applied.

Concerning the differential mud pressure, 500 lb. per sq. in. was taken to be representative of normal bottom-hole conditions and conforms approximately to conditions—for example, at the bottom of an 8000-ft. well with formation pressure of 3500 lb. per sq. in. while drilling with a 75-lb. per cu. ft. mud of which the hydrostatic pressure at 8000 ft. is 4150 lb. per sq. in. It is clear, of course, that the differential pressure between mud and the formation is the driving force in this filtration.

In every test sufficient time was allowed for apparatus, mud, and core to reach temperature equilibrium with the water bath, which encloses both the circulating pump and pressure bomb. Loss of filtrate by evaporation at the high temperatures was avoided by water-jacketing the filtrate-exit tube.

For purposes of analysis, the filtrate volume at the end of 45 min. was taken to represent the plastering behavior. During the runs, however, the filtrate volume was determined at one-minute intervals for the first five minutes and at suitable longer intervals until the end of the run. The thickness of the mud sheath was measured at the termination of the run, after the core had been removed from the apparatus and the excess loose mud washed off.

Stock muds that had been completely hydrated by standing in contact with water for several weeks with frequent agitation were used.

The viscosity of each mud at the temperature of the runs was measured with the Störmer viscometer at 600 r.p.m., using the standard cup with baffle, for possible use in the interpretation of the results.

As the study of consolidated cores required some modification of the apparatus as described by Jones and Babson for unconsolidated sand packs, a special core holder was used (Fig. 1).

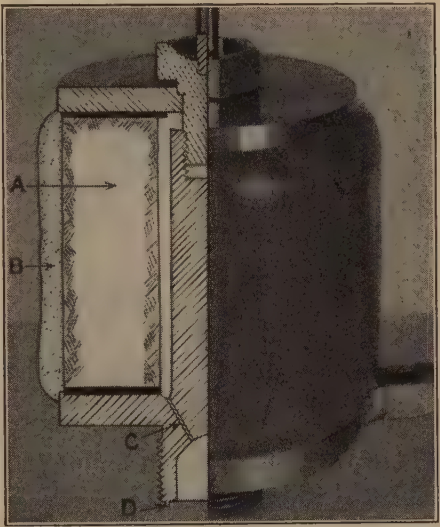

FIG. 1.—MOUNTING FOR CONSOLIDATED CORES.
A, cylindrical core.
B, mud sheath.
C, drainage ports for filtrate.
D, crown seat connection through bottom of pressure vessel.

The same core was used over and over again, but only after experiment had demonstrated that check results could be obtained consistently provided the mud sheath after each experiment was removed by flowing clean water under pressure in the reverse direction; i.e., from the inside to the outside. This operation required only a few minutes, and usually was carried out while other adjustments and preparations for the following run were being made.

As was expected, the water loss and sheath thickness increased markedly over the temperature range studied. For the range 70° to 175° F. the increase in water loss varied from mud to mud between 63.8 per cent for 75 lb. untreated Mojave mud and 227 per cent for 70 lb. treated Lebec mud, as shown in Table 1. In Fig. 2 are plotted the cumulative water losses at the end of 45 min. (core area = 180.4 sq. cm.) for each mud at the five temperatures studied. As shown by this set of curves, the order of plastering at low temperature may be reversed at high temperature, since the slopes of these curves are different and may cross at temperatures still higher than the upper limit of this study.

In attempting to interpret the results of the temperature effect, we have applied the expressions used by Larsen,[4] which state that the cumulative quantity of filtrate Q for a given time at any elevated temperature is related to the filtrate for the same length of time at some other temperature by a factor equal to the square root of the ratios of the viscosities (η) of water at the two temperatures,* e.g.,

TABLE 1.—*Percentage Increase in Water Loss from* 70° *to* 175° *F.*

	Mud	Untreated, Per Cent	Treated with Quebracho Soda, Per Cent
1	75 lb. Ventura gray	102.5	
2	79 lb. Ventura gray	91.5	41.8
3	75 lb. Ventura brown	126	92.0
4	75 lb. Mojave	63.8	
5	85 lb. Mojave	68.5	169
6	75 lb. Palos Verdes	157.5	85.0
7	75 lb. McKittrick	71.4	220
8	70 lb. Lebec	105.5	227
9	75 lb. Ventura brown[a]		137

[a] Mud treated to same final viscosity with sodium pyrophosphate instead of with quebracho soda as in experiment 3 above.

$$\text{Percentage increase} = \frac{\text{water loss at } 175^\circ - \text{water loss at } 70^\circ}{\text{water loss at } 70^\circ} \times 100$$

$$Q_{175^\circ} = Q_{70^\circ} \times \sqrt{\frac{\eta_{70^\circ}}{\eta_{175^\circ}}}$$

or

$$Q_T \times \sqrt{\eta_T} = \text{constant}$$

The validity of this relation was tested by observing the constancy of this product. Supposedly constant if the above hypothesis is correct, this product was found to increase appreciably with increasing temperature for most of the muds tested. The deviations from the values obtained from the expression above have been plotted in Figs. 3 and 4 for untreated and treated muds, respectively. Illustrative of the erroneous results likely to be obtained by this relation, untreated Palos Verdes mud shows an expected water loss of 266 c.c. at 175° F. based on the measured value of 160 c.c. at 70° whereas the measured value at 175° was 412 c.c., or 2.575 times the water loss at 70°. This corresponds to a deviation of 55 per cent from the value based on the above expression.

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* These expressions may be derived directly from the fundamental filtration equation. Comparison runs in a static filter press using filter paper as the porous medium (linear flow) demonstrate that the conclusions arrived at on the basis of radial flow with circulation apply equally well to static filtration runs although absolute values of water loss are not identical.

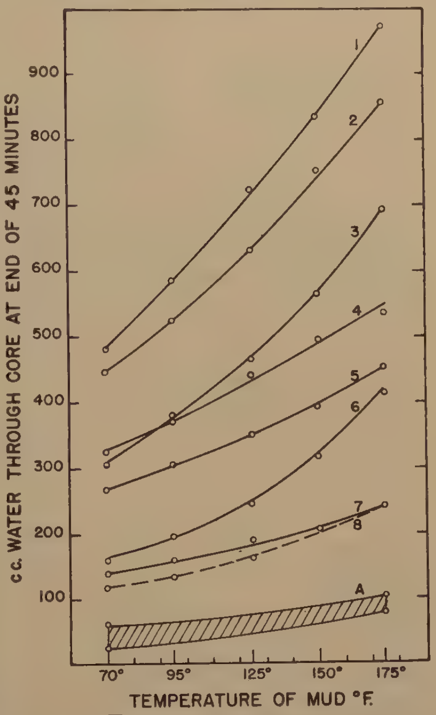

Fig. 2.—Effect of temperature on plastering.

1. 75 lb. Ventura gray.
2. 79 lb. Ventura gray.
3. 75 lb. Ventura brown.
4. 75 lb. Mojave.
5. 85 lb. Mojave.
6. 75 lb. Palos Verdes.
7. 75 lb. McKittrick.
8. 70 lb. Lebec.

A. Chemically treated muds 2, 3, 5, 6, 7, 8 fall within this range.

Similar large deviations were observed with nearly all of the untreated muds except Mojave. Larsen also found this mud to show but little deviation, although he found several other muds, designated as anomalous, which deviated considerably. It is evident from the data as a whole that as a rule factors other than the change in viscosity of water in the mud play a major part in the effect of temperature on plastering of muds, and that it is unsafe to make predictions of the high-temperature behavior using the above relation. Measurements at high temperature, preferably the anticipated well temperature, will in general be necessary.

Still larger deviations, up to 98 per cent, were obtained with muds treated with quebracho soda. Further, the deviation appears to be unrelated to the presence or absence of chemical treating agents, the mud showing largest deviation when untreated shows a low deviation when treated with quebracho soda, while the muds showing medium deviation untreated show high deviation when treated.

It was found that the average permeability of the mud sheath at the end of the run increased steadily with increasing temperature. Such an increase in permeability is characteristic of flocculation and it may be inferred that temperature flocculation, mentioned earlier, is the cause for the discrepancy between calculated and experimental results. It is interesting to note that the permeability is essentially constant for the mud that obeys the relationship described above.

TABLE 2.—*Change in Permeability of Mud Sheath with Temperature*

Temperature, Deg. F.	Permeability of Sheath, Darcies	
	75 Lb. Palos Verdes Mud	75 Lb. Mojave Mud
70	2.2×10^{-6}	6.5×10^{-6}
95	2.5×10^{-6}	5.9×10^{-6}
125	2.7×10^{-6}	5.8×10^{-6}
150	3.8×10^{-6}	5.8×10^{-6}
175	4.5×10^{-6}	5.9×10^{-6}

The measured values of mud-sheath permeability for two representative examples (75 lb. untreated Palos Verdes mud), showing large deviation from this expression, and 75 lb. untreated Mojave, which follows this expression closely (Fig. 3), are given in Table 2. To obtain these data, the rate of flow during the last 15 min. of the run, together with the final mud-sheath thickness and the viscosity of water

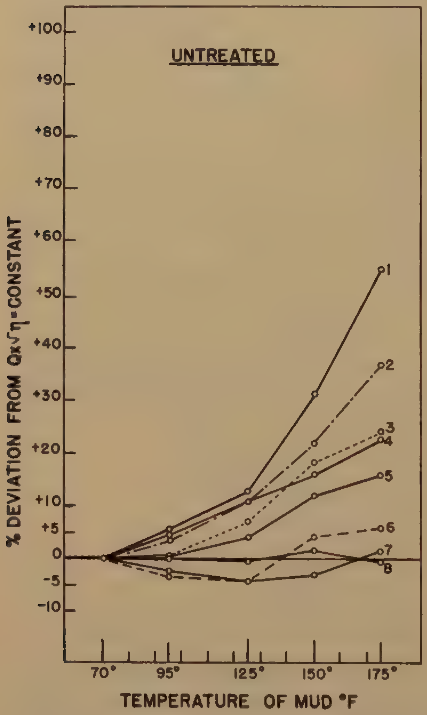

FIG. 3.

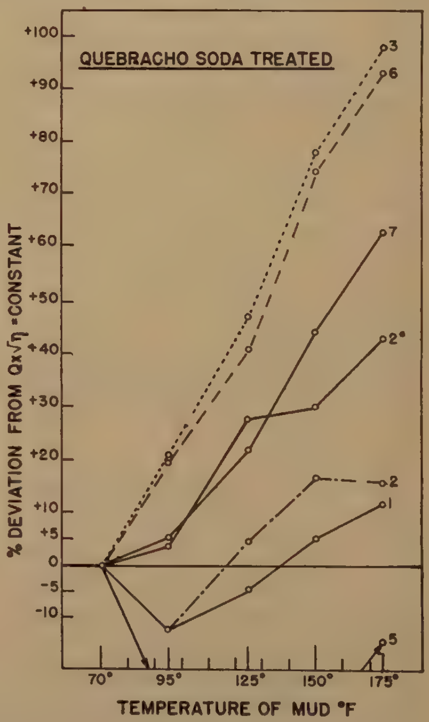

FIG. 4.

FIGS. 3 AND 4.—DEVIATION FROM THEORETICAL EXPRESSION $Q \times \sqrt{\eta}$ = CONSTANT.

1. 75 lb. Palos Verdes.
2. 75 lb. brown Ventura.

2.* 75 lb. brown Ventura treated with pyrophosphate.

3. 70 lb. Lebec.
4. 75 lb. gray Ventura.
5. 79 lb. gray Ventura.
6. 75 lb. McKittrick.
7. 85 lb. Mojave.
8. 75 lb. Mojave.

at each temperature, were substituted in the familiar equation for permeability k, as follows:

$$k = \frac{\mu \cdot dQ/dt \cdot h}{A\Delta P} = \text{permeability in darcies}$$

when μ is viscosity in centipoises, dQ/dt is the rate of flow of water in cubic centimeters per second through the sheath thickness h, in centimeters, under a pressure difference of ΔP atmospheres.

It appears possible, also, to obtain a lower water loss at elevated temperature than can be explained solely from considerations of the change in the viscosity of water (see, for example, 79 lb. treated Ventura gray, curve 5, Fig. 4) although the results here are less convincing than in the other experiments. In view of the results so far presented, it appears necessary either to determine the plastering properties at the temperature anticipated in the well or to measure the plastering properties at a number of temperatures approaching the temperature anticipated in the well, making a *short* extrapolation of the curve through these measured points to the temperature in question.

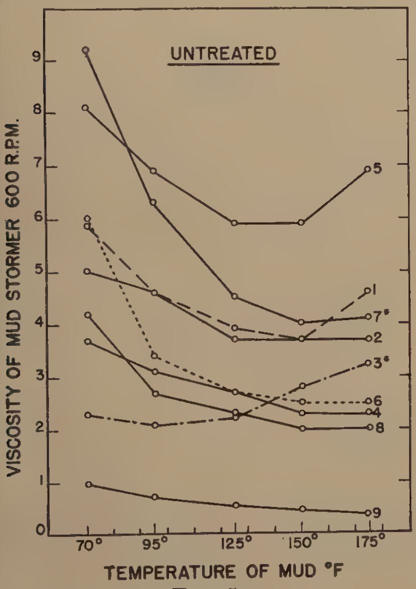

FIG. 5.

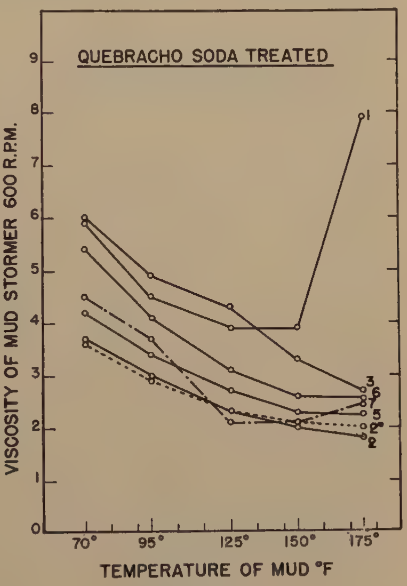

FIG. 6.

FIGS. 5 AND 6.—EFFECT OF TEMPERATURE UPON VISCOSITY OF DRILLING MUDS.

1. 75 lb. Palos Verdes.
2. 75 lb. brown Ventura.
2.* 75 lb. brown Ventura (pyrophosphate treated).
3.* 70 lb. Lebec (1/10 scale).
4. 75 lb. gray Ventura.
5. 79 lb. gray Ventura.
6. 75 lb. McKittrick.
7.* 85 lb. Mojave (1/10 scale).
8. 75 lb. Mojave.
9. Distilled water.

Since, as is evident from the data presented here, each mud yielded a different curve of filtrate versus temperature, such a curve must be determined for each mud, and under the conditions of actual use.

This behavior of the plastering properties applies to a wide variety of muds showing water losses at room temperature of from 120 to 450 c.c. (at end of 45 min. at 500 lb. pressure and core area of 180.4 sq. cm.) and appears to be unrelated to the inherent colloidal character of the mud.

The viscosity of each of the muds over the temperature range 70° to 175° is presented in Figs. 5 and 6, the first for untreated muds, the second for muds treated with quebracho soda. The distinct minimum in viscosity shown by Craft and Exner[6] is evident for several of the untreated muds, although the temperature for minimum viscosity appears to vary over a wide range from mud to mud, as well as for different densities of the same mud. For example, with 79 lb. Ventura gray the minimum viscosity occurs at about 130° to 140°, whereas with the same mud at 75 lb. per cu. ft. the minimum viscosity is apparently just approached at 175° F. A similar shift in minimum viscosity to lower temperatures with increased mud weight is evident with 75 lb. and 85 lb. Mojave muds. Lebec mud, on the other hand, shows a minimum viscosity at about 80° to 90°, the viscosity rising at temperatures above this value. Chemically treated muds, on the other hand, in general show a shift of the temperature of minimum viscosity to still higher values (Fig. 6). The minima lie higher than 175° F., the upper limit of the present experiments. There appears to be no relation between mud viscosity and plastering properties of these muds.

REFERENCES

1. Jones and Babson: Evaluation of Rotary Drilling Muds. Drill. and Prod. Practice, Amer. Petr. Inst. (1935) 22.
2. Williams and Cannon: Evaluation of Filtration Properties of Drilling Muds. *Oil Weekly* (1938) **90**, 25.
3. P. H. Jones: Field Control of Drilling Mud. Drill. and Prod. Practice, Amer. Petr. Inst. (1937) 24.
4. D. H. Larsen: Methods of Determining the Filtration Characteristics of Drilling Muds. *Petr. Eng.* (Sept., Nov. 1938).
5. D. H. Larsen: Loss of Water to Oil-Bearing Sands as a Basic Cause of Low Production. *Drilling Mud* (April, 1937).
6 Craft and Exner: *Trans.* A.I.M.E. (1933) **103**, 112.

DISCUSSION

(*R. E. Allen presiding*)

N. JOHNSTON,* Los Angeles, Calif.—Dr. Byck has presented some interesting data on drilling mud at elevated temperatures. His statement that mud properties under drilling conditions are so difficult to predict from laboratory tests at room temperature is, unfortunately, correct at present. There is little hope that it will become possible in the near future to predict physical properties under other than test conditions, as this would require the development of an artificial, pure, or reproducible drilling fluid that would be free from contamination during drilling, thus maintaining its original properties at all times. Such a development seems very unlikely at present, so it appears necessary to continue to test actual muds under actual drilling conditions of temperature, and even to repeat these tests frequently, as many native muds vary from year to year.

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* General Petroleum Corporation of California.

The second point I wish to comment on is that of temperatures of drilling mud during normal drilling. Of course, when circulation is suspended for 12 hr. or longer, the contents of a bore hole will approach thermal equilibrium with the surroundings. That is, the upper part of the hole will cool off and the lower part will warm up to a condition approaching the normal, static geothermal gradient. However, during normal circulation, there will be a radical redistribution of heat content of the hole, the gradient being greatly lessened (for example, from 1° F. per 60 ft. for the static case, to 1°F. per 300 ft.), though the total heat content of the well may not be materially changed. The heat content will probably be slightly decreased because of starting with cold mud and the continued evaporation from ditch and pit. To offset these effects are the higher thermal conductivity of the deeper rocks and the frictional heat from drilling, which may in some places overbalance the cooling effects.

These are theoretical considerations. I am much interested in actual field data on bottom-hole mud temperatures during normal mud circulation. Various methods are available for obtaining such data, yet very little attention has been paid to this study, in spite of its obvious importance in both mud testing and cement placing. One test in California shows a bottom-hole static temperature at a depth of 11,300 ft. to be reduced from 248° to 165°F. by circulation at about 30 cu. ft. per minute for 16 hr., while the top-hole mud temperature has risen to 131°F. from an annual average surface temperature of 62°F. The simple average of circulation temperature of the mud (148°F.) is thus 7°F. lower than the static average (155°F.), which appears reasonable. In another case a circulation rate of 50 cu. ft. per minute for 14 hr. reduced the differential between top and bottom-hole temperatures to only 19°F., the actual temperatures being 141°F. at the surface and 160°F. at 9100 ft. The "circulation gradient" here was only 1°F. per 480 ft., while in the former case it was 1°F. per 300 feet.

I should be glad to discuss such thermal measurements with anyone interested in making a further study of well temperatures. I should like to emphasize here the necessity of an accurate knowledge of the circulation history of a hole before a temperature measurement is considered as having any significance.

D. H. Larsen,* Los Angeles, Calif.—Dr. Byck has presented a paper of considerable interest for those interested in drilling mud, and especially for California operators, inasmuch as basically useful data are included for specific California clays.

It may be noted in passing that the equation

$$Q_t \times \sqrt{\eta_T} = \text{Constant}$$

does not purport to describe the behavior of all actual drilling muds, but rather: "Water-loss multiplied by the square root of filtrate viscosity gives an index to the water-loss independent of filtration viscosity, and thus enables one to judge the effect of temperature on the mud itself" (ref. 4, p. 60).

We have found this relation to be of particular value in correcting to a standard temperature of 68°F. filtration determinations made at slightly different room and field temperatures, varying perhaps from 55° to 95°F. As is apparent from Fig. 3, a mud that is "anomalous" at a high temperature becomes disproportionately more so as the temperature is increased; i.e., if α is percentage of deviation and T temperature,

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* Baroid Sales Division, National Lead Co.

$$\frac{d^2\alpha}{dT^2}$$

is positive in the range 70° to 150°F. for muds of Fig. 3 that show a large deviation. Thus it appears that for small temperature corrections in the neighborhood of 68°F. the relation is relatively valid even for muds extremely adversely affected by temperature. It is to be stressed that this use of the equation is in contradistinction to its use as a means of eliminating one variable factor (i.e., filtrate viscosity) when the filtration behavior of a mud is being studied at widely different temperatures.

A further distinction between reversible and irreversible "temperature-anomaly" is useful; many muds that suffer disproportionately larger water losses upon being heated will not when cooled and retested at room temperature yield as low a value of water loss as originally obtained. This is most marked in chemically treated muds, as the chemical undergoes depolymerization, hydration, oxidation, precipitation, etc., according to its nature, upon prolonged heating. On the other hand, many muds, especially muds that have circulated some time in a drilling well, exhibit a low-temperature water loss unchanged by heating and subsequent cooling.

A Study of Some Phases of Chemical Control in Clay Suspensions

By Allen D. Garrison* and K. C. ten Brink†

(Galveston Meeting, October 1939)

A previous paper[1] reviewed some of the properties of clays and shales and presented some data on the nature of the gelling phenomenon. It included a brief discussion of origin of clays and shales, their composition, structure, retention of water, ionization, base exchange, and the nature of the gelling of water suspensions. Other publications of the Institute[2–8] have discussed the properties of clays and their relations to drilling-fluid behavior and control. It is the purpose of this article to present some new data obtained and arranged in a different manner and making possible a better understanding of the chemical reactions involved in the control of drilling-fluid characteristics during the normal drilling operations.

Experimental Procedure

The difficulties involved in the measurements of the flow characteristics of plastic fluids are too familiar to recite. The possible applications of some of the well-known instruments to this problem have been adequately discussed by Hobson[9] and he has given an excellent bibliography. Although there are many viscosimeters of varied design, none of them appear to fulfill the most obvious demands of accuracy in the measurement of clay or shale suspensions. Since the fluid characteristics are dependent on the rate of flow of the fluid, and the viscosity usually falls off very rapidly as the rate is increased, it is clear that the first requirement is that the instrument shall be capable of a wide variety of speeds. The viscosity of the fluid at any fixed and constant rate of flow is also a function of time, so that the second demand is that the instrument shall be capable of a constant and continuous motion for a prolonged period of time.

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[1] References are at the end of the paper.

The only commonly available instrument that partly meets these two demands is the Mac Michael viscosimeter, but that instrument is not well adapted to the variety of speeds demanded and the damping of the instrument is not adequate to deal with drilling-fluid consistency.

The third requirement involves the design of the cup that contains the sample. It is important that all of the sample under observation shall be flowing smoothly at as nearly the same rate as possible. It is not desirable to have any variety of vanes or baffles, since this causes a part of the fluid to assume one viscosity while another part assumes another. It is also clear that the sample under observation must be thin enough in section to avoid channeling.

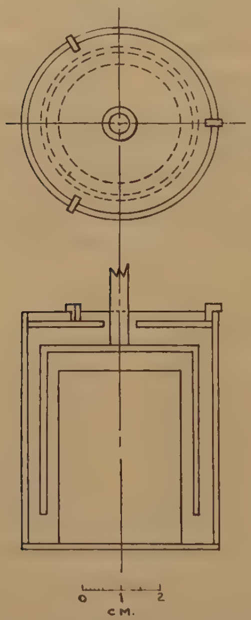

Fig. 1.—Viscosimeter cup and rotor.

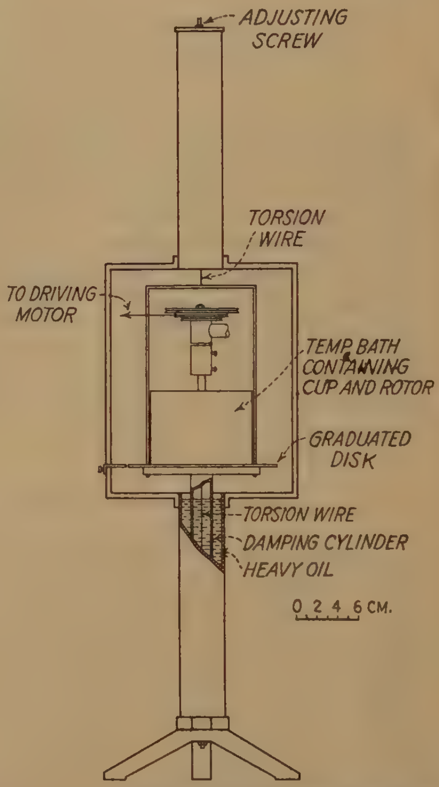

Fig. 2.—Improved torsion viscosimeter.

The instrument illustrated in Figs. 1 and 2 was designed and constructed to conform as nearly as possible to these fundamental requirements.

The sample to be measured, about 50 c.c. in volume, is contained in a Monel metal cup (Fig. 1). The center of the cup is filled with a hollow, closed cylinder thus forming an annular space between the wall of the cup and the inner cylinder. The rotating member, also made of Monel metal, consists of a cylinder with shaft attached at the closed end and so mounted within the cup that the space about the rotor on all sides is uniform. A Monel metal lid closes the top of the cup except for the opening for the shaft.

The cup containing the sample is mounted in a cast aluminum water bath and supported as indicated in Fig. 2. The rotor is driven through a rubber belt by a variable-speed electric motor with automatic speed control, and the speed is indicated stroboscopically. The stroboscope disk is mounted on the pulley wheel at the upper end of the rotor shaft, is scaled with black and white spots to indicate speeds of 100, 200, 400, 600, and 800 r.p.m., and is illuminated by a neon light on a synchronous 60-cycle current.

The cup and water bath rest on a graduated disk suspended on a steel torsion wire and free to rotate through about 150°. Vibrations are damped heavily by the brass cylinder, which extends from the lower side of the graduated disk down into heavy oil. The torque at any desired speed may thus be read from the deflection of the graduated disk, and the observations may be continued over as long a period as desired.

The instrument was carefully calibrated with purely viscous liquids consisting of glycerin and water. The concentrations of the glycerin solutions were determined by refractive index measurements and the viscosities were obtained from Sheely's data.[9] The calibration lines were straight, and the deflections were almost proportional to speeds, indicating that substantially streamline fluid motion was obtained. These calibration charts were used to convert the angle of deflection into absolute viscosity, so that any plastic fluid could be accurately compared with a purely viscous one in the same cup and at the same rate of flow. Thus, the viscosity of a clay or shale suspension is reported in centipoises, and at a certain speed expressed in revolutions per minute of the rotor. We have learned that this procedure is definitely better than attempting to correlate results simply in terms of the angle of deflection. There is enough deviation from ideal flow conditions even in concentric cylinder cups with smooth walls to justify a careful calibration at all contemplated speeds with fluids of known characteristics.

The outer diameter of the rotor is 1⅝ in. and the clearance both inside and out ⅛ in. This section of fluid is thin enough and the area of the rotor nearly enough the area of the cup walls that the plastic fluids were not observed to channel close to the rotor, as they sometimes do in cups with relatively small rotors. The Stormer instrument is particularly unsuitable in this respect.

The fluid samples were poured into the cup until there was about one millimeter of fluid over the top of the lid. Any evaporation taking place during a measurement was thus confined to a static upper layer, which was not involved in the measurement. For particularly long runs it is convenient to place a small secondary lid, consisting of a disk of damp blotting paper, over the cup to provide a vapor-saturated atmosphere over the sample.

BEHAVIOR OF SUSPENSIONS OF VARIOUS SOLIDS

The characteristics of the instrument that has just been described have been studied using suspensions of various types of solids in water. The viscosity of a clay suspension in water subjected to steady flow is dependent upon the time the observation is made after the motion is started. The viscosity starts at a relatively high value when the first motion starts, and as the motion continues the viscosity gradually falls to a value that may remain constant for an indefinite period of time. The viscosity may pass through a minimum and ultimately rise to higher values as motion is continued, but that phenomenon requires special conditions and will not be considered in this article. The data to be presented were obtained during approximately equilibrium conditions when the viscosities had attained steady values. Fig. 3 presents the results of measurements made upon 38 per cent, 31 per cent and 20 per cent kaolin suspensions. The equilibrium values determined at 800, 600, 400, 200 and 100 r.p.m. lie on approximately straight lines provided

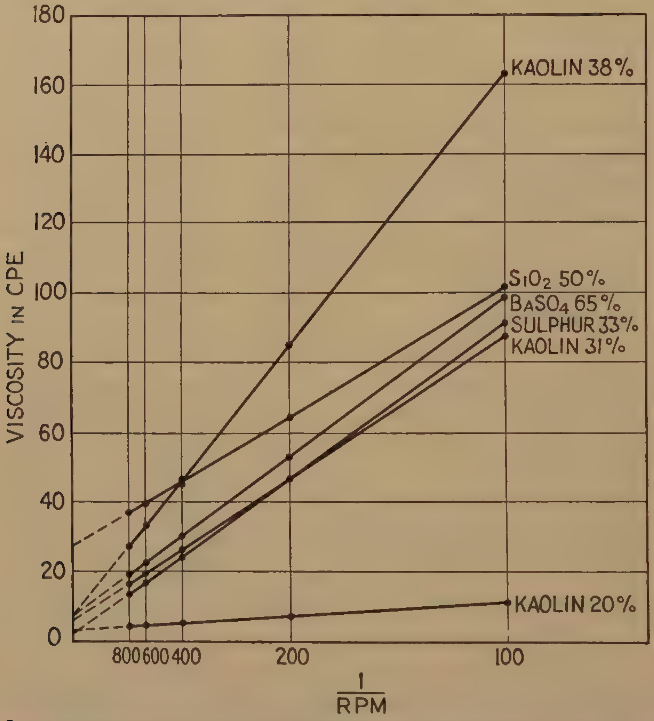

FIG. 3.—MEASUREMENTS ON KAOLIN SUSPENSIONS, AMORPHOUS SILICA, SULPHUR AND BARIUM SULPHATE IN WATER, PER CENT BY WEIGHT.

the actual viscosity in centipoises is plotted on the Y-axis and the reciprocal of the revolutions per minute are plotted on the X-axis. The same type of speed-viscosity relation is obtained from all of the suspensions of kaolin in water. The lines are all straight and slopes are in the order of the concentration. The intercepts are in the order of the concentration.

A number of solids of different chemical and physical nature when suspended in water were found to have substantially the same speed-viscosity relations. Fig. 3 also presents the results of a suspension of 50 per cent amorphous silica in water, 33 per cent finely divided sulphur in water, and 65 per cent finely divided barium sulphate in water. The chemical nature of these suspended solids is quite different, in that the amorphous silica has a high adhesion tension relative to water, the finely divided sulphur has a low adhesion tension relative to water, and the barium sulphate has an intermediate adhesion tension relative to water. The particle sizes of these suspensions vary in a manner that was not definitely determined, but it is clear from an examination of Fig. 3 that the nature of speed-viscosity relationship is substantially the same as that of suspended kaolin. The slopes of the lines differ in individual cases, and the intercepts of the lines—the viscosity that would be obtained by extrapolating the relationship to an infinitely rapid rate of flow—also differ in individual cases. It appears to be a general principle that this intercept is higher the greater the relative volume of the suspended solids, and that the slope is higher the greater the tendency of the solid particles to adhere together. The latter condition obtains when the concentration is high and the adhesion tension is low.

It should be noted that the method used in plotting the results of experimental observations by comparing viscosities with the reciprocal of the rate of rotation of the rotor of the instrument is substantially different from the usual method of plotting the viscosity of a fluid against the force causing the flow, and subsequent extrapolation for the so-called "yield value." The results of measurements on a purely viscous liquid recorded in the manner used in Fig. 3 would yield a horizontal line of constant viscosity, whatever the rate of flow, provided that rate did not enter the turbulent zone. The results of this method of plotting the experimental data appear to indicate that the viscosities of solid suspensions are becoming higher in almost direct proportion to the reduction in the rate of fluid motion, and this appears to indicate that the slopes of these lines are quantitative measures of the tendencies of the various suspended particles to adhere together in the medium. It is believed that this method makes an obvious distinction between the part of the viscosity of the suspension that is due to the obstruction to flow caused by the rigid particles of solid, which Einstein has accounted for in his well-known viscosity equation, and the portion of viscosity that is due to the relatively rigid attachment of the particles at the points at which they come in contact. The latter may be called "structural viscosity." It appears that the more rapid the rate of flow in the cases of the suspensions mentioned, the smaller becomes that part of the viscosity that is due to the interparticle forces of attraction. Thus the intercept referred to above may be taken to be that part of the viscosity for which Einstein made his correction as distinguished from the part that may be caused by particle attractions.

Suspensions of bentonitic clays have been recognized to be quite different from suspensions of less colloidal particles, chiefly in that less bentonitic material is required to cause a substantial increase in the viscosity of the suspension. Bentonitic clays have also been recognized to be those clays subject to the greatest degree of swelling when moistened with water. Fig. 4 shows that the viscosity-speed relations for suspensions of bentonite in water studied under the conditions described above are substantially different from the suspensions of relatively noncolloidal solids that were illustrated in Fig. 3. The results of the two suspensions, one having 7 per cent and the other 6 per cent of Wyoming bentonite, are shown in Fig. 4. It is clear that the viscosities of these suspensions, although the same precautions were taken to obtain the equilibrium values at the various speeds, do not bear the same relationship to one another that was found in Fig. 3.

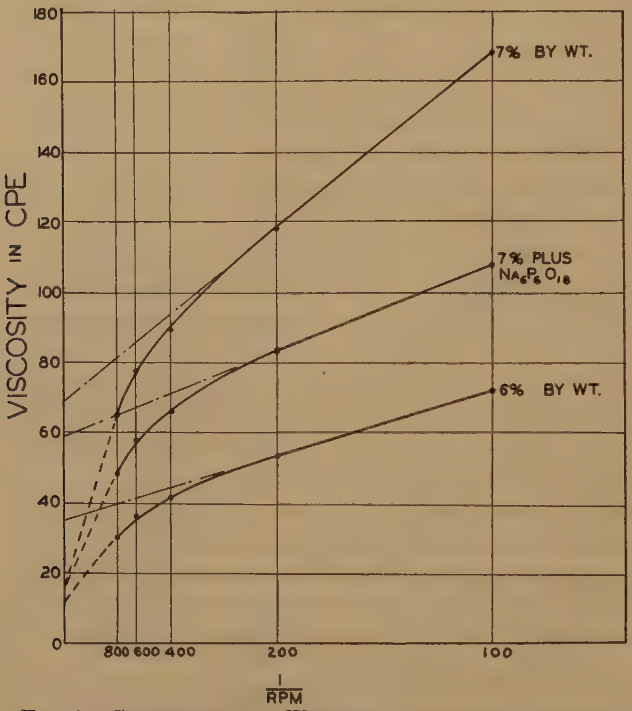

FIG. 4.—SUSPENSIONS OF WYOMING BENTONITE IN WATER.

These curved lines are definitely associated with the smaller particles of the bentonitic clay. Fig. 5 illustrates this principle. The same sample of Wyoming bentonite illustrated in Fig. 4 was suspended in water in small concentration, and was fractionated by passing through a supercentrifuge. Three fractions were separated, which for the sake of simplicity will be called coarse, fine and very fine. These fractions were placed in water in the same concentration, 4 per cent, and the viscosity characteristics determined. Extrapolation of the low speed values (100 and 200 r.p.m.) of viscosity into the high-speed region would yield an intercept for the very fine fraction that is much higher than that obtained by the extrapolation of the low-speed viscosities of the fine fraction, and both of these are substantially above the viscosity obtained by extrapolating the viscosities of the coarse fraction.

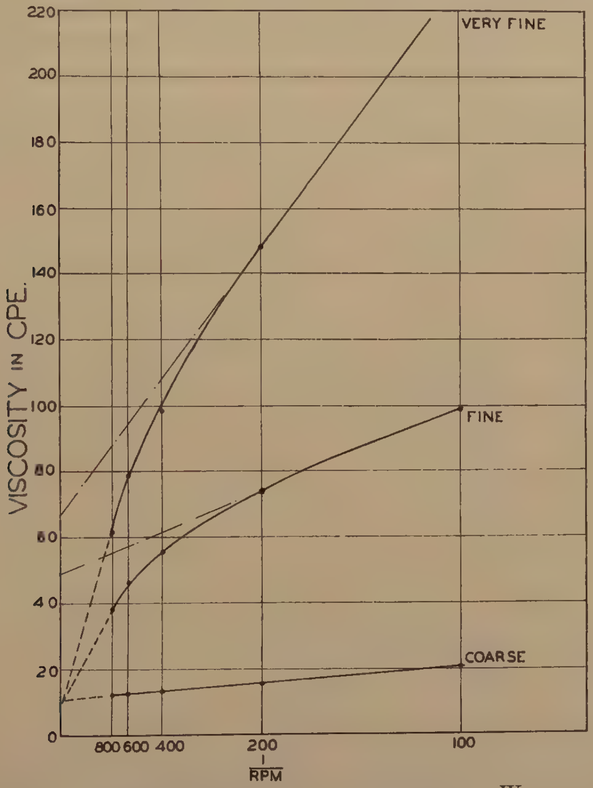

Fig. 5.—Viscosity characteristics of fractionated Wyoming bentonite. Bentonite 4 per cent by weight.

Effect of Deflocculating Agents

There are differences in the manner in which these suspensions react when treated with small amounts of deflocculating agents. Fig. 6 presents the results of measurements of viscosities of a 7 per cent

Wyoming bentonite and of a 38 per cent kaolin suspension, both before and after the addition of the two well-known deflocculating agents, the plant tannins and sodium hexametaphosphate. The viscosities of the two suspensions prior to the treatment when determined at 100 r.p.m. were substantially the same, although the viscosities determined at higher speeds were smaller in the kaolin suspension and, as pointed out above, lie approximately upon a straight line for kaolin and a curved line for bentonite. After the determination of these viscosities, 0.1 gram of oak-bark tannin per 100 c.c. of suspension was added in each case, together with enough potassium hydroxide to raise the pH+ to approximately 10. Fig. 6 shows that the viscosities of the kaolin suspension were lowered to relatively low values and that these values still lie approximately upon a straight line. On the other hand, the viscosities of the bentonite suspension were not lowered in the same degree. The greatest lowering appeared when the suspension was measured at low speed, 100 r.p.m. A smaller reduction appeared at the speed of 200 r.p.m., and a still smaller reduction at the high speeds. The effect is to cause the line to appear with a greater degree of curvature than it had prior to the treatment. One-tenth of a gram of sodium hexametaphosphate was then added to each of the samples and the viscosities again determined at the various speeds. Again it may be seen that the behavior of the two types of clays was entirely different. The inter-

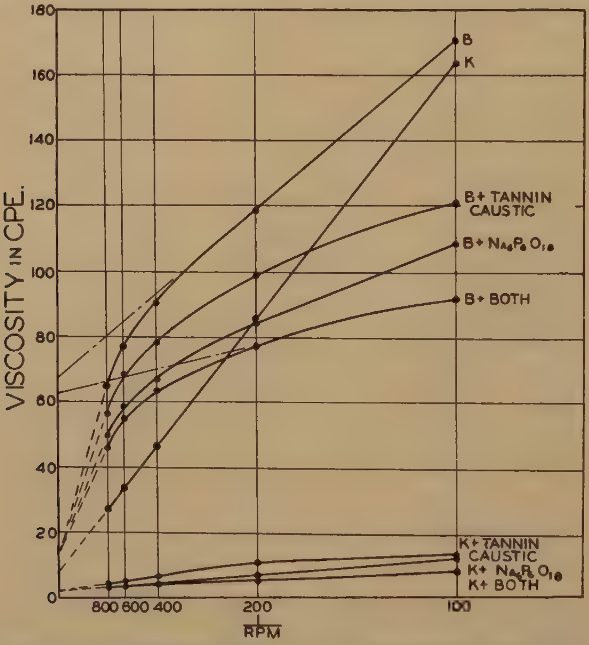

Fig. 6.—Viscosities before and after deflocculation. *B*, 7 per cent Wyoming bentonite; *K*, 38 per cent kaolin.

cepts are substantially uninfluenced by the addition of the chemical deflocculating agents, and are very high for the bentonite as compared to the kaolin suspensions.

Fig. 6 also contains the results of an addition of both deflocculating agents to each of the suspensions. The deflocculation obtained by the combined action is greater than by the individual action of the agents, but the extrapolation of the low-speed values of the bentonite would give a value well above 60 centipoises, whereas the corresponding intercept for kaolin is approximately 2 centipoises. These characteristics are even more remarkable than the fact that the bentonite concentration was less than one-fifth that of the kaolin. It is also noteworthy that the slopes of the lines through the low-speed values are not appreciably different in the two cases.

We believe that Fig. 6 offers a particularly good illustration of the various factors that contribute to the viscosity of a clay suspension: (1) viscosity of the water medium itself, which in this case is very low, about 1 centipoise; (2) the viscosity normally attributed to the obstruction offered by the rigid solid particles and accounted for in the Einstein equation referred to; (3) the forces acting between the suspended particles and tending toward the setting up of a relatively rigid structure through the suspension medium; and (4) a factor that has been referred to in the past as hydration. It is commonly recognized that the higher colloidal bentonitic clays that are capable of a high degree of swelling when moistened with water possess this property because of their ability to develop layers of combined water upon their surfaces.[10] A relatively small part of the viscosity may be attributed to the solid volume (factor 2), but the high viscosities observed, particularly in the highly colloidal bentonite, are very many times larger than the viscosity that would be attributed to the obstruction offered by the rigid particles. It appears that the two major factors contributing to the high viscosity in both of the above cases are the attractive forces and the hydration listed as items 3 and 4 above. We believe that our data provide evidence that the chemical deflocculating agents are instrumental in lowering the attractive forces between the particles and thus reducing viscosity of a suspension in so far as these attractive forces contribute to it, but that they are not instrumental in lowering the part of the viscosity that is due to the hydration of the colloidal clay particles. In Fig. 6 it may be seen that the bentonite that has a relatively high intercept is relatively slightly influenced by the chemical deflocculating agents, whereas the kaolin suspension having a relatively small intercept is substantially influenced by the chemical deflocculating agents. In a previous paper,[1] it has been pointed out that the alkaline tannates are instrumental in lowering the rate at which a gel is set up in a bentonite suspension, and here again we attribute the lowering of the viscosity of the bentonite suspension to the weakening or retardation of the formation of attachments between the bentonite particles in so far as this viscosity may have been due to these gelling forces. We conclude that the alkaline tannates under the conditions listed above are not instrumental in removing the layers of hydrated water from the surfaces of the clay particles, partly from the fact that the chemical treatment was not capable of reducing the viscosity of the suspension below the value at the intercept.

In the practice of reducing the viscosity of drilling fluids by the addition of deflocculating agents, it has often been observed that some fluids respond to the treatment to a much greater extent than others. This may be attributed in part to the fact that shales are composed of a mixture of both of the clay types illustrated in the explanation above. Even with the complication of other factors, such as previous chemical treatment, salt contamination and differing content of total solids, it is possible to obtain drilling fluids containing different relative amounts of the highly colloidal and highly hydrated clays in proportion to the less colloidal and practically unhydrated clays. These suspensions will respond differently, depending upon what fraction of the total viscosity may be attributed to the gelling or structural forces and what fraction to the hydration of the highly colloidal parts of the suspension.

If this explanation of the curvature of the speed-viscosity lines is correct, it appears that the hydration of the clay is partly reduced by the fluid motion at the highest speeds. This is not inconsistent with the surface chemistry of the clay particles. Hydrated water is now believed to appear[10] in multiple layers of hexagonal nets, each successive net having a weaker force of attachment than the layers nearer the surface of the particle. The outer layers are held by such weak forces that they may be easily stripped off by motions that are rapid enough to approach the turbulent zone.

It is thus reasonable to suppose that the extrapolation of the low-speed viscosities would give the Einstein volumetric effect of the completely hydrated particles, whereas the extrapolation of the high-speed values would give Einstein volumetric effect of the particles stripped of their nets of hydrated water.

Additional evidence that the interpretation of the viscosity lines of bentonite given above is correct may be obtained from a study of the viscosity curves at different temperatures. Fig. 7 presents the results of such an investigation. The suspension of Wyoming bentonite and water containing 7 per cent of the natural Wyoming bentonite was aged for a sufficient time to permit the hydration and swelling to become pronounced. Its viscosity was first studied at the temperature of 26° C. and the results are shown in Fig. 7, having the characteristic appreciable curvature. The temperature was then raised, and measurements made at higher temperatures. The extrapolation of each of these lines from the low-speed values will yield intercepts that continually become smaller as the temperature increases. In effect, the line becomes more nearly a straight line at a high temperature and the slope is substantially increased. It cannot be said with accuracy that the viscosity is either increased or decreased without stating the exact speed at which the determination was made. By comparing any two temperatures, it may be seen that there is some speed at which the viscosity does not change at all, and that below this speed the viscosity is increased by increasing temperature, and above this speed the viscosity is decreased by increasing temperature. It is well recognized that hydration of colloidal clays is reduced by raising the temperature. Our interpretation of the curvature of the bentonite lines is thus substantiated if one simply assumes that the reduction of the hydration due to increasing the temperature thins the films of hydrated water about the particles and lowers that part of the viscosity that is due to hydration, but in doing so increases the speed of gelling both by making it possible for the particles to approach more closely and by increasing the speed of their motion. Thus the

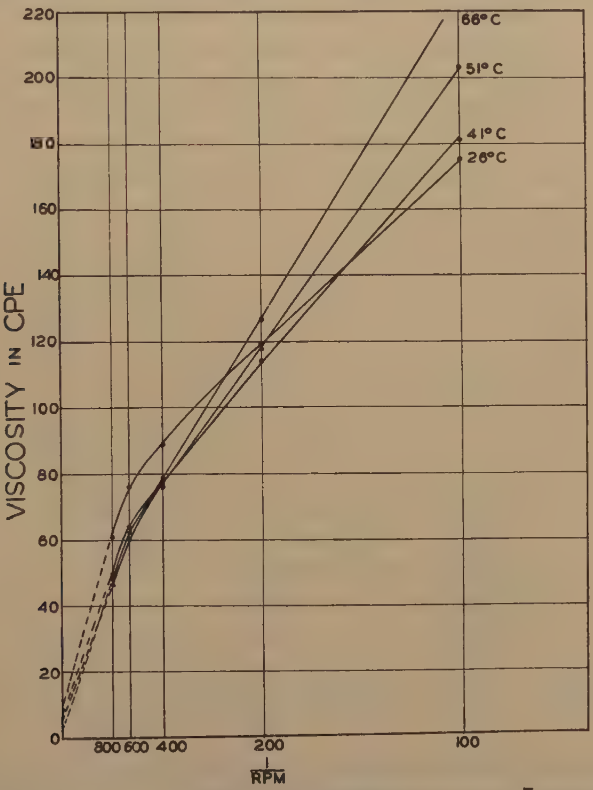

Fig. 7.—Viscosity lines at various temperatures, 7 per cent Wyoming bentonite.

increasing temperature increases the part of the viscosity that is due to structural attachments between the particles, while decreasing the part of the viscosity that is due to hydration.

INFLUENCE OF pH+ AND METALLIC IONS

Further evidence of the extent to which factors of gel structure and hydration are subject to the customary methods of chemical control has been obtained from a study of suspensions of highly colloidal bentonitic clay after all of the exchangeable metallic ions had been removed from it by electrodialysis, and also after metallic ions of different nature had been returned to the bentonitic structure. Fig. 8 presents the data that were obtained from a study of 5 per cent electrodialyzed Wyoming bentonite to which the sodium ions were returned by successive additions of sodium hydroxide. The electrodialyzed bentonite had a pH+ of 2, and the particles in this suspension were relatively large, resembling in size the kaolin particles. The viscosities of this suspension fall very nearly upon a straight line with a relatively low intercept (Fig. 8). The first small addition of sodium hydroxide sufficient to raise the pH+ to 2.7 produced a deflocculating effect upon the suspension, indicated by the

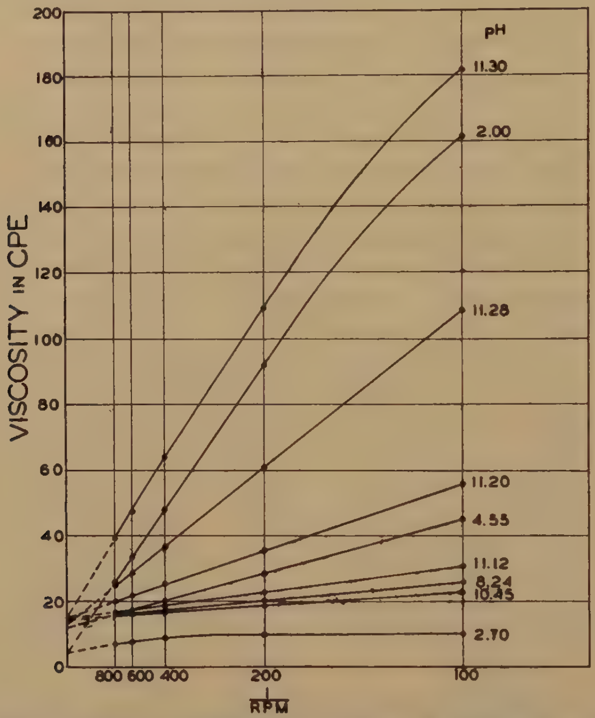

FIG. 8.—VISCOSITY LINES AT VARIOUS pH+ VALUES, 5 PER CENT ELECTRODIALYZED WYOMING BENTONITE PLUS SODIUM HYDROXIDE.

fact that the viscosity was reduced to approximately 10 centipoises at 100 r.p.m. The points obtained by making measurements at the higher speeds lie very nearly upon a straight line. Successive additions of sodium hydroxide as indicated in Fig. 8 cause a substantial increase in the intercept values. This increase seems to occur at the point where the pH+ was observed to be about 4.5, although the slope of the line at that pH+ does not indicate appreciable flocculation. Increasing pH+ beyond the value of 4.5 again lowers the slope of the line, indicating increased deflocculation while at the same time maintaining the relatively high intercept. The slope again became steep when the pH+ of 11 was exceeded. Although the percentage of Wyoming bentonite is too low to exhibit the high intercepts observed in Figs. 4 and 5, the slope of the line where the pH+ is 11.3 is approximately the same as the slope of the line where the pH+ is 2, and the intercept has been increased by the addition of sodium hydroxide. It is noteworthy that the bentonite when electrodialyzed to a pH+ of 2 to 2.7 does not show the phenomenon of swelling, and that an increase in pH+ beyond this relatively low range causes a simultaneous swelling and rise of the value of the intercept.

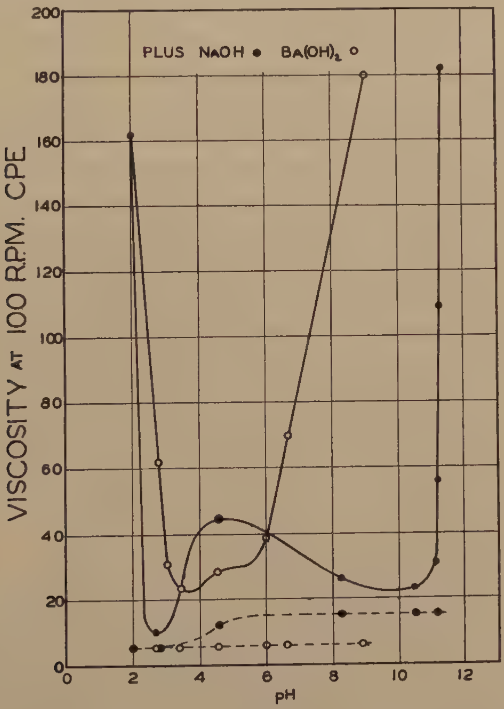

Fig. 9.—Viscosities at 100 revolutions per minute.

Fig. 9 presents these data in a different manner. The viscosities determined at 100 r.p.m. are plotted in this figure on the *Y*-axis, the pH+ on the *X*-axis. A dotted line is also placed on the figure to show how the intercepts depend upon the amount of the base added.

These experiments were duplicated using barium hydroxide instead of sodium hydroxide. Fig. 9 contains also the curve obtained by plotting the viscosities measured at 100 r.p.m. against the pH+, which was increased by the addition of barium hydroxide. A second dotted line is also placed on this figure to show the intercepts of the several lines in this second case. In general, the same results were obtained when barium hydroxide was added but there were two noteworthy exceptions: (1) After the small additions of barium hydroxide had lowered the viscosity to a minimum, successive additions caused a much more rapid rise in the slope of the lines and in the viscosity when measured at 100 r.p.m.; (2) the intercepts of the lines for barium were almost exactly the same on all lines. These results are to be anticipated from the recognized fact that the sodium bentonite swells and hydrates in water to a much greater extent than the barium bentonite. The failure of the barium bentonite to increase the value of the intercept as the pH+ is raised is further evidence that we have obtained substantially a measure of the part of the viscosity that may be attributed to hydration.

It is noteworthy that a minimum in the low-speed viscosity falls within the region 9.5 to 10.5 pH+ for the sodium clay (Fig. 9). It has been previously indicated that this corresponds to the position of the minimum gel rate.[1] In field practice in the treatment of drilling fluids it has been found that the deflocculating effect of the plant tannins appears to be a maximum within this pH+ region, and it is therefore frequently recommended that drilling fluids be maintained within this region for optimum viscosity reduction.

Conditions of drilling may make this recommendation inadvisable. Many natural clays and marine shales are composed of mixtures of clays and other solids. They contain sodium, calcium, and other exchangeable metals. Both the hydratable and nonhydratable clay types are present. Our experiments indicate definitely that the deflocculating procedure that consists of the addition of alkaline plant tannins functions by lowering the structural viscosity without substantially influencing the part of the viscosity that is due to hydration of the more colloidal parts of the shale. In another paper it will be demonstrated that this high pH+ policy is not always advisable when it is desirable to maintain as low a viscosity as possible, since it has been found that certain fractions of the shales and clays that are not originally in the hydrated condition become hydrated at the higher pH+ values. Our experiments have shown that an increase in colloidal dispersion and subsequent increase in hydration may occur within this high pH+ region, which more than offsets the reduction in viscosity attained through the ability of the deflocculating agent to reduce structural viscosity.

The usual method of measuring the viscosity of drilling fluid with the Marsh funnel is unfortunate in that it is impossible to measure the viscosity at any fixed rate of flow. The method inherently involves a measurement of differences in rate of flow. When the viscosity appears to rise, it is impossible to tell with this instrument whether the rise in viscosity is due to increased hydration of the more colloidal portions of the shale or to the structural factor of viscosity.

These results (Figs. 3 to 9) explain to some extent the conflicting observations made upon the action of deflocculating agents in the field by the use of funnel instruments. In some cases it may be observed that the fluids do not respond at all to the addition of the chemical deflocculating agents, while in others reductions in viscosity are observed that are either large or small for reasons that cannot be ascertained by the funnel instruments.

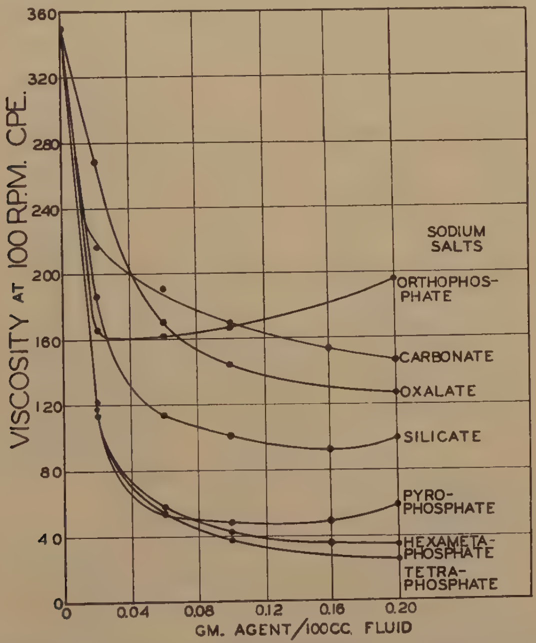

FIG. 10.—EFFECTS OF VARIOUS DEFLOCCULATING AGENTS. NATURAL MIOCENE SHALE SUSPENSION, 30 PER CENT BY WEIGHT.

EFFECT OF VARIOUS SODIUM SALTS

The nature of the effect of the addition of other well-known deflocculating agents upon the viscosity characteristics of clays and shales in suspension has been shown by our instrument to be similar to that obtained by the addition of the molecularly dehydrated phosphates and the plant tannins. Fig. 10 presents the results of a study of a number of sodium salts known to be deflocculating agents. The suspension involved in this study was a typical marine shale from the Gulf Coast region, containing approximately 30 per cent of total solids in suspension. An appreciable fraction of this shale was bentonitic in nature. Each of the deflocculating agents was added to a sample of this suspension in various amounts, and the viscosities were determined at various speeds. Fig. 10 presents the viscosities measured at the speed of 100 r.p.m. as a function of the amount of material added to the suspension. In all of these cases it was found that the viscosity reduction may be attributed to the lowering of the forces of attachment between the suspended particles and that the intercepts of the viscosity lines were not materially influenced by the deflocculating agents.

The effects of these deflocculating agents have been attributed in the past to various factors. One of these is known to be the ability of the deflocculating agent to remove the calcium and magnesium ions. This factor is not the predominating one (Fig. 10), since the order of the deflocculating ability is not the same as the order of the solubility of the alkaline-earth salts. Two other explanations have been offered, the first involving an increase in the electric charge due to the adsorption of the negatively charged ions, the second involving the blocking of the broken bonds on the surface of the clay grains. Whatever the mechanism determining the deflocculation, our experiments indicate that the portion of the viscosity that may be attributed to the hydration is not substantially reduced, but that the observed change in viscosity may be attributed to a reduction in the structural factor.

Fig. 10 discloses another reason for the failure of certain deflocculating agents to function after they have been used for a period of time in drilling-fluid practice. For example, if sodium pyrophosphate had been used in drilling operations for several days, it may be that the addition of the chemical has reached a minimum on the curve for that material illustrated in Fig. 10. It would then be observed that further additions of this deflocculating material would cause a rise in the viscosity rather than a lowering. It is important in the chemical control of drilling fluid that this phenomenon be recognized and that the failure of the chemical deflocculating agent from this cause be distinguished from failure from the other causes that have been mentioned. It is noteworthy that the neutral molecularly dehydrated phosphates do not exhibit this reversal of effect within the range of the amounts usually added.

Chemical Reduction of the Hydration

We have presented some experimental evidence in Fig. 11 to show that carefully controlled chemical treatments may result in varied types of viscosity characteristics. A 7 per cent Wyoming bentonite suspension measured in a manner already described was treated with 0.1 gram of sodium hexametaphosphate per 100 c.c. of suspension. The curvature of the viscosity line was increased (Fig. 11) and the viscosity reduction appeared principally in the low-speed values. Another sample of the 7 per cent suspension was treated with barium hydroxide until the pH+ was 11.2. The suspension was allowed 96 hr. to attain an equilibrium with the barium hydroxide and the measurements of viscosities were then made, taking the usual precautions to permit the viscosity to attain equilibrium at each speed. The results are shown in Fig. 11. This sample was then treated with carbon dioxide gas until the pH+ was lowered to 7.8, which removed the excess of the barium ions that had not become adsorbed on the clay and at the same time removed any calcium or magnesium that may have been displaced from the clay by base exchange. The clay was thus converted to some extent into a barium clay. Since barium is a divalent ion and at the same time relatively less hydrated than the ions that formerly were present on the clay, it might be expected that the factor of viscosity due to hydration would be reduced. It might also be expected that the barium clay would be more easily flocculated and would therefore have a higher viscosity due to the struc-

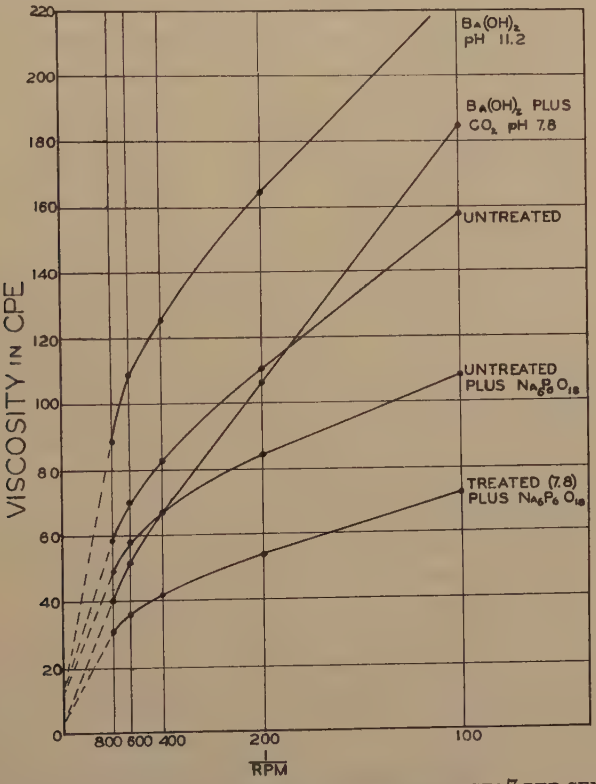

FIG. 11.—DEFLOCCULATION ACCOMPANIED BY IONIC EXCHANGE; 7 PER CENT BENTONITE.

tural attachments between the clay particles. That both of these results were obtained may be ascertained from examination of the resulting viscosity relationship.

This suspension was then treated with 0.1 gram of sodium hexametaphosphate, with the results indicated in Fig. 11. It is clear that the viscosity reduction at all speeds is greater in this case than in the deflocculation of the original untreated bentonite suspension with the hexametaphosphate alone. The lines are similar in curvature, the upper portions of the lines are similar in slope, but the intercepts obtained by extrapolating the low-speed values to infinite speed are remarkably different. This illustrates the fact that it may be possible to lower both the structural factor and the hydration factor of viscosity, provided the clay is deflocculated under conditions that favor a reduction in hydration.

The deflocculating agents that have been commonly used in the past appear to be those that influence structural viscosity only. To control hydration is a manipulation that is not so simple. It involves such methods as an exchange of ions on the clay surface for less hydrated ions, or a complete removal of these ions such as is obtained during electrodialysis, or the dehydrating effect of an excess of some water-soluble salt, or the addition of dehydrating liquids, such as alcohol or acetone.

Fig. 12 further illustrates the factors of viscosity discussed above. The left-hand side of the figure shows clay in two states of dispersion, but both of them in the flocculated state. The condition illustrated in the upper part of the figure is one of relatively large particles composed of a multitude of primary crystal laminations. These large particles are flocculated, meaning that they adhere together in flocks or loosely attached groups of particles, which trap water very much in the manner in which a sponge holds water.

The right-hand part of the figure shows a clay in two different conditions of colloidal dispersion, but both in a deflocculated state. The condition illustrated in the upper right-hand position is one in which the large secondary clay grains remain intact, but relatively free to move about in the suspension as contrasted with the flocculated condition in which the particles had a great tendency to adhere together. The lower right-hand portion of the figure illustrates the increased colloidal dispersion of clay by a more complete separation of the larger particles into their smaller lamellar crystals. It is well recognized that this separation takes place more easily with the lithium and sodium clays and that it is favored by a negative electric charge on the clay particles. It is also recognized that the separation into individual crystal sheets is accompanied by hydration, which in this figure is illustrated by a dotted line surrounding the small particles. In describing the chemical treatment of clay suspensions, these different forms must be distinguished in more accurate terminology. It is consistent with the origin of the words and with their usage in colloid chemistry to refer to the changes indicated in Fig. 12 by the arrows 1 and 2 as "deflocculation" and "flocculation," respectively. This is equally accurate whether the flocculation or deflocculation occurs in a very highly colloidal or hydrated material, or applies to coarser suspended particles.

The changes indicated by arrows 3 and 4 may simply be described as "increased colloidal dispersion" or "decreased colloidal dispersion."

In the practical chemical control of drilling fluid, it is also necessary to distinguish and adjust the factors that favor the different forms; for example, during the drilling of formations that do not contribute to the colloidal material of the drilling fluid in appreciable amounts, it is desirable to add to the drilling fluid just enough of the highly hydrated and highly dispersed form illustrated in the lower right-hand part of the figure to maintain the proper physical characteristics of the fluid. The amount of materials of this kind would remain approximately constant under the drilling conditions outlined.

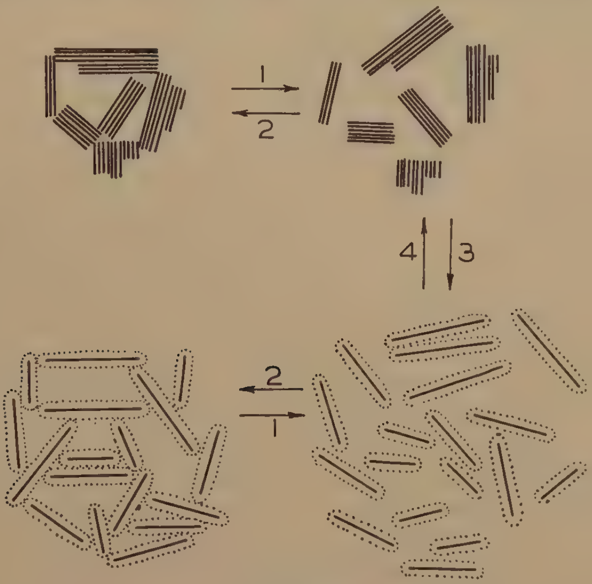

FIG. 12.—DIAGRAM OF DISPERSION OF CLAY.

But during the drilling of more bentonitic clays, and particularly during the drilling of the more colloidal marine shales, it is found that the highly dispersed and highly hydrated colloidal form may spontaneously increase to excessive amounts. It is therefore important in these cases to recognize that the chemical control should be directed only to the maintenance of deflocculation under conditions that do not favor any tendency to increase in dispersion and hydration. This is all the more important when it is necessary to add weighting material to the drilling fluid. Another article will present a study of some of the factors that determine the increased colloidal dispersion of clays and natural shales during conditions that are common to the usual drilling procedure.

REFERENCES

1. Garrison: *Trans.* A.I.M.E. (1939) **132,** 191.
2. Craft and Exner: *Trans.* A.I.M.E. (1933) **103,** 112.
3. Burke: *Trans.* A.I.M.E. (1935) **114,** 53.
4. Lewis, Squires and Thompson: *Trans.* A.I.M.E. (1935) **114,** 38; and (1936) **118,** 71.
5. Gross: *Trans.* A.I.M.E. (1938) **127,** 263.
6. Reed: *Trans.* A.I.M.E. (1938) **127,** 240.
7. Routh and Craft: A.I.M.E. *Tech. Pub.* 961 (*Petr. Tech.*, Aug. 1938).
8. Broughton and Hand: A.I.M.E. *Tech. Pub.* 1002 (*Petr. Tech.*, Nov. 1938).
9. Hobson: *Jnl.* Inst. Petr. Tech. (1935) **21,** 204.
10. Hendricks and Jefferson: *Amer. Miner* (1938) **23,** 863.

Dispersion of Clays and Shales by Fluid Motion

By Allen D. Garrison,* K. C. ten Brink† and P. B. Elkin†

(Galveston Meeting, October 1939)

It is the purpose of this article to present the results of an investigation of certain clay and shale suspensions having viscosities that are materially influenced by fluid motion, and to discuss the bearing of these results upon the choice of policy in the control of drilling fluids. A previous article described the design and the characteristics of an instrument adapted to measure the viscosity of plastic suspensions during continuous uniform motion and at a variety of speeds.[1]

It has long been recognized that the viscosity of a clay suspension depends on the past history of the fluid motion. Since an abundance of literature is available on this phenomenon,[2] it is not necessary to describe it in more than general terms. It is usually observed that rapid motion reduces the viscosity of a clay suspension, and that some time is required for the viscosity to fall to its equilibrium value after the steady motion is started. On reducing the speed of motion to some lower value, the viscosity again rises, but it also requires some time to attain a steady viscosity value at the slower rate of motion. Thus clay suspensions are usually observed to be increasing in viscosity as time passes when the measurement has been immediately preceded by fluid motion that was more rapid than that employed in the measurement. And it is usually observed that the viscosity falls as time passes when the measurement has been preceded by more quiescent conditions. Reed,[3] and Broughton and Hand[4] have reported a condition of observation of clay suspensions in which the viscosity was observed to fall during the first few moments of steady motion, and rise thereafter.

The characteristics of the new instrument are particularly well adapted to studies of this kind. With it we have been able to observe all of the phenomena described above, and it is important to understand their nature because they all occur at some time during normal drill-

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[1] References are at the end of the paper.

ing operations. This is particularly true of the rise in viscosity from a minimum value.

EXPERIMENTAL PROCEDURE

The viscosity instrument was operated in the manner described in the previous article.[1] Measurements made at the various speeds were recorded as a function of time. As a rule, the speed of 600 r.p.m. was chosen as the most suitable for examining the manner in which the viscosity characteristics changed during long continued liquid motion. When it was desirable to determine the viscosity characteristics of the fluid that had resulted from one of these long continued runs at 600 r.p.m., the same procedure was adopted as that already described. During the experiments the temperature was from 25° to 30° C. (room temperature), and it was not found necessary to control this temperature by thermostatic devices, since the results were not critically dependent upon slight changes in temperature.

When a fluid was to be measured, it was placed in the instrument in such a manner that the lid of the viscosity cup was flooded with fluid to a thickness of about one millimeter. In long continued runs a secondary lid consisting of a disk of blotting paper moistened with water was placed over the sample to prevent evaporation of water. The rotor was started and adjusted as quickly as possible at 600 r.p.m., and the deflections were observed at regular intervals. The instrument permits observation of the viscosity almost instantaneously at any time after the motion has started, without discontinuance of the motion or change in speed.

When a typical kaolin clay suspension was measured in this manner and the viscosities plotted on the Y-axis against time on the X-axis, it was usually observed that the viscosity was reduced rather quickly to an equilibrium value that remained constant for a relatively long period of time. It was usually observed that in clay suspensions capable of forming rigid gel structures, bentonite for example, the time required for the viscosity to fall to an equilibrium value was frequently as long as 20 to 30 min., whereas suspensions capable of forming only a weak gel structure attained a minimum viscosity in from 1 to 5 minutes.

A number of clays and shales were studied under varying conditions for periods of time ranging from a few minutes to many hours. Among these materials were typical bentonites, kaolin, Texas clays, and representative marine shales. A sample of clay obtained from central Texas and several samples of marine shale were found to exhibit the property of increasing viscosity after having passed through a minimum. Experiments were planned to study these suspensions under conditions that would permit one factor to be varied while all other significant factors were kept constant. As a result of these investigations it was found that the increase in viscosity of these fluids was dependent upon the time the clay had been suspended in the water, the concentration of the suspension, the pH+, the nature of the metallic ions associated with the clay, and the presence of certain deflocculating agents.

AGE OF THE SUSPENSION

Results of experiments directed to the determination of the effect of time of contact of the clay with water upon its viscosity characteristics are presented graphically in Fig. 1. A sample of Texas clay was suspended in water in a concentration of 20 per cent by weight. The clay contained only the water that was normally present in equilibrium with the air of the room prior to introducing it in the water suspension. Fig. 1 contains the results of three series of experiments, the first performed one hour after the water suspension was prepared, the second two days after the water suspension had been prepared, and the third nine days after the water suspension had been prepared. In each case the minimum viscosity obtained during the run appeared within the first ½ to 2 min., and after that time the viscosity rose during the run. The effect of aging is remarkable.

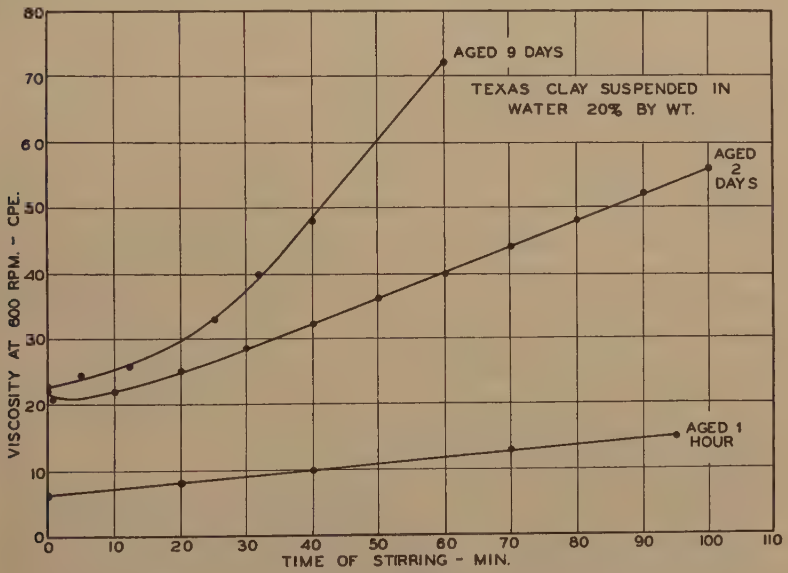

FIG. 1.—EFFECT OF TIME OF CONTACT OF CLAY WITH WATER ON VISCOSITY CHARACTERISTICS.

We have found that this is a rather common occurrence, not only for this particular sample of Texas clay but for all those samples of clays and shales that display the property of increasing viscosity during fluid motion. For this reason care was taken to keep this factor constant during the observation of the effect of varying other factors. In subsequent experiments the time of contact of the clay with water will be stated.

Concentration of Suspension

The second factor having substantial influence on the rate of increase of the viscosity during continuous fluid motion was the concentration of the suspension. Fig. 2 illustrates the extent to which this factor is important. The figure contains the results of experiments performed on the same Texas clay used in the first experiments, this sample having been aged in water for two days. Only the factor of concentration was varied in these tests. The results of the 20 per cent suspension are compared with those of the 25 per cent suspension. The increases in viscosity were uniform, but with the 25 per cent suspension much more rapid. It required 100 min. to increase the viscosity of the 20 per cent suspension from 20 to 56 centipoises; it required only 39 min. to increase the viscosity of the other from 38 to 107 centipoises. Fig. 4 also presents the results of measurements made upon a typical marine shale, of the Miocene age, which had been pulverized and dried in air and which was added to a sodium hydroxide solution 30 min. before the start of the viscosity determination. The amount of the sodium hydroxide in the water was 0.311 milliequivalents per gram of shale in each case, and the pH+ of the resulting suspension determined immediately prior to the

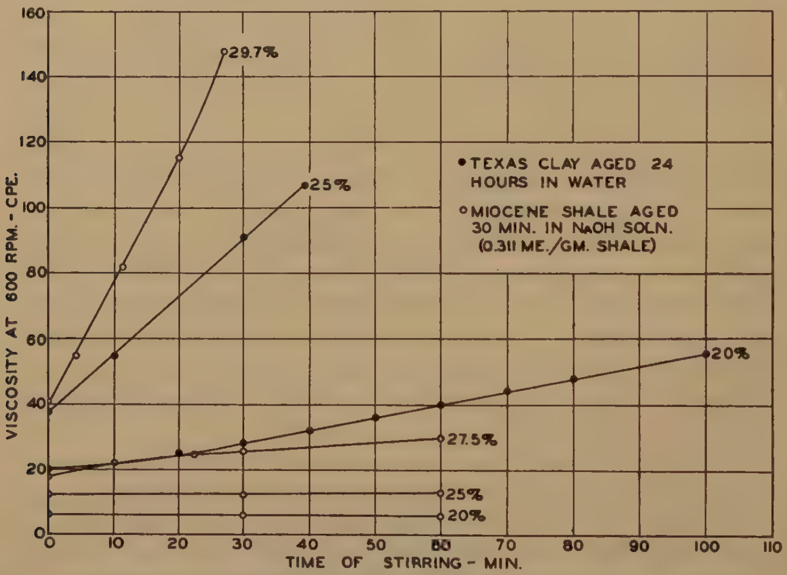

Fig. 2.—Increase of viscosity during continuous fluid motion, concentration of suspension being varied.

runs was 11.1. The experiments differ only in the concentration of the shale suspensions. It appears to be a general principle that the increase in viscosity during the fluid motion is very rapidly accelerated in the range of concentrations within which the viscosity rises rapidly with slight increases in the concentrations of suspended solids.

THE pH+ OF THE SUSPENSION

The third factor determining the rate of rise of the viscosity with time is that of alkalinity. Fig. 3 presents in graphical form the results of two series of experiments, the first performed upon a sample of Texas clay that had been suspended in water for three weeks and that contained 20 per cent by weight of clay. The second series shows the results of adding this same sample of Texas clay in the air-dried condition to the water medium 30 min. prior to the beginning of the measurements. The first series contains three experiments; the first was performed on the suspension in water alone having pH+ of 7.7; the second was the same as the first except that enough sodium hydroxide was present to raise the pH+ to 8.97; and the third was the same as the others except that enough sodium hydroxide was added to raise the pH+ to 11.18. The starting viscosities were very nearly the same; namely, 39, 40 and 42.

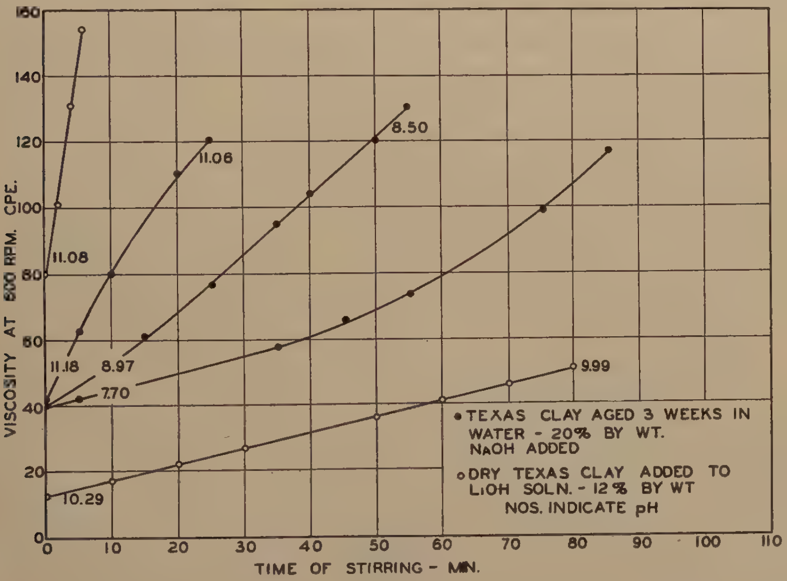

FIG. 3.—ALKALINITY AS A FACTOR IN RATE OF RISE OF VISCOSITY.

In the second series the air-dried clay was added to a lithium hydroxide solution to a concentration of 12 per cent by weight. The first experiment of this series contained 0.148 milliequivalents of lithium hydroxide per gram of clay and had a pH+ of 10.3 at the beginning of the measurement. In the second experiment 0.311 milliequivalents of lithium hydroxide were present per gram of clay, and the pH+ was 11.1. The first experiment resulted in uniform rise in viscosity from 13 to 51 in 80 min. The second experiment resulted in a rise in viscosity from 80 to 154 in 6 minutes.

It is clear that an increase in pH+ above 7 and up to at least 11.1 involves a substantial increase in the rate at which the viscosity rises during continuous motion. This principle is not specific to the sample of Texas clay, but was observed to apply as well to some representative shales.

Since it is well known that an increase in pH+ from 8 to about 11 involves a more complete exchange of the metallic ions for the hydrogen ions in the clay structure, and since it is also well known that the degree of colloidal dispersion is much higher for the lithium and sodium clays, it is logical to conclude that the very great increase in viscosity observed at high pH+ values was associated with an increase in colloidal dispersion of the clays or shales, and the resultant increase in hydration. When the experiments described below are examined with this mechanism in mind, many of the observed phenomena are consistent and to some extent predictable.

Influence of Metallic Ions

The applicability of the Hofmeister series to the base exchange properties of clays is now well recognized.[5,1] Lithium ions are more highly hydrated than sodium ions, and potassium and barium are much less hydrated. Lithium clay is therefore more highly ionized and hydrated than sodium clay, and the ionization of potassium and barium clays follows in the same order as the hydration of these ions. If a neutral clay should be made alkaline with the hydroxides of each of the metals named above, it should be found that the Hofmeister series would predict the extent of colloidal dispersion and hydration and therefore the rate of rise of viscosity with time.

A sample of Texas clay dried in air was added to solutions of the above-named metallic hydroxides to make 12 per cent suspensions. Each suspension was permitted to stand exactly 30 min. prior to the beginning of the measurement. Each suspension contained 0.311 milliequivalents of base per gram of clay. Each suspension was run continuously at 600 r.p.m., and the data obtained are presented graphically in Fig. 4.

The difference in behavior of the four suspensions is very noticeable. When these suspensions were permitted to stand for a day or more, other changes took place, which were again dependent upon the nature of the exchangeable metallic ions. These changes are also shown in Fig. 4. After 12-hr. standing, the lithium hydroxide suspension, when again subjected to a measurement at 600 r.p.m., dropped its viscosity quickly to about 55 centipoises, and again increased steadily, but not as rapidly as it had the day before. It reached a value of 86 centipoises after a total running time of 46 min. This suspension developed a substantial gel structure on standing for a period of 2 hr. and when again subjected to 600 r.p.m. exhibited the characteristic curve that is commonly observed when a thixotropic bentonite suspension is measured; namely, a relatively slow reduction in viscosity to a minimum value. In this case it required about 15 min. Here again the viscosity continued to rise during the 600-r.p.m. determination, and again at the end of 150 min. total running time demonstrated its ability to gel on standing 2 hr. For the third time it exhibited the same phenomena of reduction in viscosity during the break in the gel structure and subsequent rise with continued running until at the end of 200 min. total running time it had a viscosity of 112 centipoises.

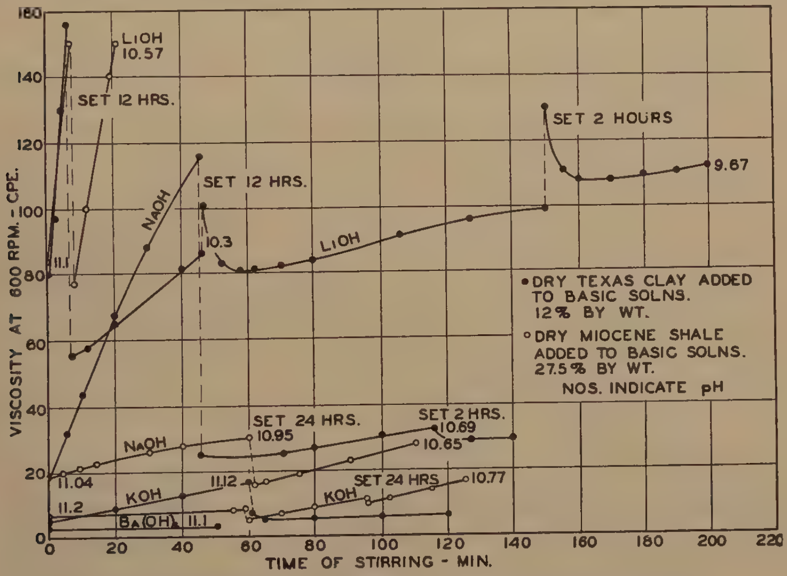

FIG. 4.—INFLUENCE OF METALLIC IONS ON INCREASE IN VISCOSITY.

During these measurements several determinations of pH+ were made, one at the end of 45 min. total running time, another at the end of 200 min. total running time. These pH+ values are indicated on Fig. 4. It is noteworthy that the pH+ continued to fall during the measurements. It is also noteworthy that the minimum viscosity that could be attained at any time during the individual measurements was steadily increasing.

The results obtained with the suspension in sodium hydroxide were similar: first, in the fact that the rest period of one day after the first measurement caused the viscosity to drop back very nearly to its original value; second, in that subsequent measurements caused substantial rise in the viscosity, although not as great as that in the lithium suspension; and third, in that there is evidence of increasing thixotropy.

The same behavior was exhibited by the potassium hydroxide suspension to a lesser degree. The barium hydroxide suspension continued to maintain the same viscosity throughout the entire period of observation.

The pH+ values observed at intervals are recorded on Fig. 4. Although the pH+ values of all the suspensions were approximately the same at the beginning of the measurements, the extent to which these values were reduced by the measurements is also in order of the Hofmeister series. The lithium clay was reduced from a pH+ of 11.1 to 9.67, while the sodium clay was reduced from 11.1 to 10.69, and the barium clay from 11.2 to 11.1.

All of these results may be interpreted satisfactorily if it is assumed that the rise in viscosity observed during the measurements is directly attributable to the increased colloidal dispersion of the clays and to the subsequent increased hydration of the small particles. The reduction in viscosity that appears during the interval of the 12-hr. rest period at the end of the first run may be attributed to chemical changes. The structure of the clay has been sufficiently disrupted by previous motion to permit the reaction of a substantial part of the base with the clay. The pH+ was thus substantially reduced. Before it was reduced and during the first run the clay was flocculated by the excess base. The condition corresponds to the point high on the curve in Fig. 9 of the previous article.[1] After the clay structure had been opened to some extent and the pH+ reduced to the range 10.3 to 11, the flocculating effect of excess base disappeared, and the condition is represented by the position of the minimum in the curve of Fig. 9 of the previous article.[1] The fact that the bases were absorbed in the order of the Hofmeister series, and that the increase in viscosity was in the order of the bases absorbed, is also compatible with the fact that increased colloidal dispersion is occurring to a greater extent in the first members of the Hofmeister series; namely, lithium and sodium.

Essentially the same results were observed in connection with a typical Miocene shale. The representative sample of the shale was pulverized and dried in air. It was placed in suspension containing 27.5 per cent solids 30 min. prior to the beginning of the viscosity measurements. Three experiments were performed with the same amount of shale, the same time of contact with water, and the same number of milliequivalents of base per gram of shale (0.311). The experiments differ only in the metallic ions. The shales behaved substantially in the same way as the clays described above.

The same relative pH+ changes were observed in the marine shale. The lithium suspension changed from 11.2 to 10.57. The sodium suspension changed from 11.04 to 10.65, and the potassium suspension from 11.2 to 10.77. The relative changes were again in the order of the Hofmeister series, both in regard to the rate of change of viscosity with time and in regard to the extent to which the pH+ was reduced.

It is possible to present rather convincing evidence that the regular increase in viscosity observed in these experiments is accompanied by a substantial increase in colloidal dispersion and hydration of the clay involved. The distribution of the particle sizes in a sample of the Texas clay was determined by a standard sedimentation method both before and after the viscosity had been increased in the suspension by long continued fluid motion. The data are presented in Table 1. Column 1 contains the ranges of particle sizes within which the determinations were made. Column 2 contains the percentages of the suspended clay appearing within the ranges specified, and determined on a 0.87 per cent suspension of the clay in water prepared simply by adding the air-dried clay sample to the water and permitting the suspension to age. Column 3 contains the results of a similar measurement of the percentages of clay falling within the same range of particle sizes, the determination having been made after a 30 per cent water suspension had been run continuously for several hours at 600 r.p.m. and after the viscosity had been observed to rise much higher than was shown in Fig. 2 for the 29.7 per cent suspension. Column 4 contains simply the difference between column 3 and column 2. It is significant that the percentage of clay within the large particle range is smaller after the long continued fluid motion. On the other hand, the percentage of clay having highly dispersed particles and smaller than 2.5×10^{-5} cm. in apparent radius is shown to have increased by more than 12 per cent. It is not possible to determine to what extent this *apparent* reduction in particle size is due to increased hydration and to what extent it is due to actual sub-

TABLE 1.—*Particle-size Distribution before and after Prolonged Viscosity Measurements at* 600 *Revolutions per Minute*

1 Apparent Spherical Radius, Cm.	2 Unstirred Clay	3 Stirred Clay	4 Difference
Greater than 7×10^{-4}	48.5	41.3	− 7.2
7.0×10^{-4} to 2.5×10^{-4}	15.4	13.5	− 1.9
2.5×10^{-4} to 1.0×10^{-4}	7.0	4.1	− 2.9
1.0×10^{-4} to 5.0×10^{-5}	5.4	4.1	− 1.3
5.0×10^{-5} to 2.5×10^{-5}	3.7	4.5	+ 0.8
Less than 2.5×10^{-5}	19.9	32.4	+12.5

division. It is clear, however, that the two effects are intimately associated. It is well known that the clays that are highly colloidal are also the clays that display the greatest degree of hydration and swelling. It may be said briefly that the long continued fluid motion has rendered the clays and shales more highly colloidal in nature.

Each of the factors (Figs. 1 to 4) contributing to the extent of this colloidal dispersion may be explained by reference to the established clay chemistry. For example, it is known that the time of contact of the clay with water determines the extent of hydration and swelling.[6] It is reasonable to expect that fluid motion and the resultant tendency to disrupt the clay particles would be more effective not only after the clay had been in contact with water for a long period of time but also when the concentration of the suspension is high enough to develop large frictional forces. The pH+ effect, which has been described, and the appearance of the Hofmeister series in connection with the metallic ions are also consistent with accepted clay chemistry.

Changes during Drilling Operations

There are a number of factors which have already been recognized to influence the rise in the viscosity of drilling fluid during normal drilling operations. Among these factors are: the accumulation of a larger amount of total solids; the exchange of metallic ions between the clays of the drilling fluid and the shales of the formation drilled; the loss of deflocculating agents; the presence of flocculating salts in the natural water of the formation drilled; and unfavorable changes in temperature. We believe that our experiments definitely indicate that the factor of the increased colloidal dispersion and hydration of the natural clays and shales must also be added to this list, and must be subjected to considerable study before we may obtain a complete solution to the problem of control of drilling fluid.

Undoubtedly, the accumulation of solids during drilling is closely related to this increased dispersion. When drilling in shale, it is possible to have most of the cuttings formed at the bit large enough to be completely removed by the screens; but during the passage up to the surface, these cuttings are subjected to the grinding action of the drill stem and to the influence of rapid fluid motion. The cuttings may be so disintegrated by this action that a large fraction may pass through the screens and remain in the fluid. The cohesion acting between the ultimate individual particles of each shale fragment oppose this grinding action. These forces of cohesion are fundamentally the same, whether the original aggregate is large in size or near the colloidal zone. Thus, any circumstances that favor the weakening of the cohesive forces, and the increased dispersion and hydration of the shale, will also increase the fraction of the shale passing the screens.

After shale fragments have passed the screens, their presence may not become immediately apparent by measuring the viscosity. But as time elapses (Fig. 1), under the influence of fluid motion, particularly when there are already appreciable solids present (Fig. 2), dispersion advances. The viscosity is increased, for several reasons: (1) there are produced a greater number of individual grains capable of building a gel structure and thus contributing to the structural viscosity; (2) particles are released within the colloidal range and, if capable of hydration, increase that part of the viscosity that is contributed by the factor of hydration; (3) new surface areas are developed, and there may be a deficiency of deflocculating agent to completely cover these new areas and prevent flocculation; and (4) base exchange between the drilling-fluid clays and the marine shales may release metallic ions that are more flocculating in nature (Fig. 4). These difficulties are not immediately evident at the time the solid content of the drilling fluid rises; they develop later and are the result of increased dispersion.

It is noteworthy that this phenomenon is subject to some chemical control. Elementary factors have already been demonstrated. Some retardation of the effect may be obtained by a drastic reduction in the total solid content (Fig. 2) of the fluid and by a restoration of the density, if necessary, by solids of higher specific gravity than clay. Deflocculating agents help by lowering interparticle friction, but it is not advisable to combat this problem with adjustments to high pH+ values. It may be possible to obtain better temporary deflocculation in this region, but if shale dispersion is promoted as rapidly as it was in the test of Fig. 3, the immediate improvement in viscosity may be more than offset by accelerated dispersion of shale fragments.

References

1. Garrison and ten Brink: Page 175, this volume.
2. Hobson: *Jnl.* Inst. Petr. Tech. (1935) **21,** 204.
3. Reed: *Trans.* A.I.M.E. (1938) **127,** 240.
4. Broughton and Hand: A.I.M.E. *Tech. Pub.* 1002 (*Petr. Tech.*, Nov. 1938).
5. Jenny and Reitemeier: *Jnl. Phys. Chem.* (1935) **39,** 593.
6. Bradley, Grim and Clark: *Ztsch. Kristallog.* (1937) **97-A,** 216.

Chapter III. Petroleum Economics

The Economics of Overdevelopment

By John D. Gill*

(New York Meeting, February 1939)

The purpose of this paper is to invite attention away from the obvious. direct monetary costs of oil-field overdevelopment (as distinguished from "social costs") to a consideration of the role played by the exercise of freedom to create even allegedly excessive[1] plant facilities in contributing to the maintenance of equilibrium in the whole economy and in promoting material progress.

The obvious and most commonly discussed effect of overdevelopment of oil fields is illustrated by the allegation that already the excessive development of the East Texas field has cost upward of $162,000,000;[2] in other words, the drilling of 12,500 wells more than the number estimated as the requirement for economical recovery of the reserve has unnecessarily raised the total cost of development that amount.

Many other illustrations of so-called excessive development of oil pools could be presented. Some of them, like Cushing, Powell and Long Beach, might be drawn from the era antedating widespread discussion in the trade of such matters as optimum well spacing, reservoir energy, the conservation rate of depletion of reserves, etc. Numerous other cases can be found in the records of the current era, which began with the introduction of rationalized restriction of production. Besides East Texas, there may be mentioned Oklahoma City, Centralia and, more recently, the town-lot development of Bloomingdale, Michigan.

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[1] It should be made clear that the author is trying neither to justify nor condone avoidable, uneconomic waste in any function of industry nor to disparage the fullest economic utilization of technical knowledge. The aim is to show the need for a broad view of the economy, including the important relationships between its competitive and complementary parts as contrasted to a narrow, provincial view which emphasizes individual gain or loss rather than the general good. Moreover, it is only because of a conviction that the conclusions to be drawn from the experience of the oil industry have a wide application to industry in general that the author has undertaken to discuss the subject.

[2] Committee of Nine's Report on Unnecessary Drilling in Proven Oil Fields. *Oil Weekly* (Dec. 28, 1936).

Persons Responsible for Overdevelopment

Early in any analysis of overdevelopment, consideration should be given to the competence and other attributes of the persons responsible for the alleged waste. The motives that prompted the developments said to be excessive should be ascertained. A series of questions might be asked having to do with the sanity, wisdom, business judgment, etc., of these operators (essentially, in the language of economists, entrepreneurs) and also regarding the ownership of capital risked in the overdevelopment and whether the investors knew that excessive development would increase the total monetary cost of production.

Mostly, these operators have been experienced men, accustomed to taking risks in investments; informed, progressive, ambitious, industrious and, reputedly, contributors to the technical development of the industry and to the material progress of the country. Of course they knew that their particular drillings would add to the total monetary cost of the development. Undoubtedly, they thought their operations would be profitable to them. Economically, if there was no more suitable outlet for their energies and capital, this would be a sufficient reason for participation in the alleged overdevelopment. Moreover, in many instances, it has not been an idle reason. In numerous pools, lease subdivisions clearly have effected increases in the density of development beyond the assumed necessity but have yielded a satisfactory return on capital to most of the participants.

Economically, these operators were not, nor was it necessary for them to be, concerned over the effect of their drillings upon other persons. An irrational regard for the effect of economic conduct on the material welfare of particular individuals or relatively small groups of individuals may result in an unwholesome freezing of the entire economy. On all sides now our system of enterprise is threatened with emasculation and our economic progress retarded. Consider the implications of an apparently simple situation, which involves no moral turpitude, no desire to injure a neighbor or disregard the Golden Rule. Visualize a small town that boasts one good hardware store. The proprietor earns a very satisfactory living and feels a sense of security in his business. Another man opens another store. He has no wish to injure the owner of the first store, nevertheless his efforts reduce the income of the first dealer because the operation of a second store does not materially, if at all, increase the town's demand for hardware. Should the second dealer be restrained? Compare the effect of so-called superfluous wells on total recovery of oil reserves.

The presumption is warranted that these persons would not have risked their capital in oil field *over*development if they could have found more promising opportunities for investment in other fields. Not thoughtlessly would they choose the intense competition that invariably characterizes overdevelopment. Consequently, in the eyes of economically minded critics of overdevelopment, they cannot be censured for pursuing self-interest. Even the technically minded critics, who have been most vocal in their objections to overdevelopment, might soften their criticisms and, perhaps, modify their conclusions after an examination of the whole economic situation of which any particular overdevelopment is only a small part. Then it might be clear to them also that the estimated wastes of labor and materials in duplicatory effort are not as grievous as the consequences that spring from the stagnation of economic activity when attempts are made to avoid overdevelopment by legislative and other arbitrary prohibitions.

Effect of Overdevelopment on Price

Moreover, the apparently logical assumption that overdevelopment must increase the price of a commodity to the consumer may not survive close examination. Also, it comprehends only one side of the economic equation—the direct monetary costs of production—while it ignores completely the other side of the equation, which represents monetary purchasing power of potential consumers. It is not safe to assume, on the one hand, that all of the benefits accruing from the use of the latest method of well spacing and other production engineering technique will be passed on to the public nor, on the other hand, that consumers will have to pay higher prices for products because of the additional cost of the duplicatory effort. Indeed, it is quite possible, as was stated by another student of the subject, that under certain circumstances excessive drilling effects a lowering of the price to the consumer:

> The drilling of wells over the amount necessary to satisfy the market demand without waste has a dual effect as a natural price depressant, for reserves are not only made more immediately available to the market thereby but the lower allowable per well decreases the margin of profit and, by thus increasing the amount of distress oil, increases the urge to overproduce.[3]

An understanding of the factual basis of these statements may be gained by considering a few assumed situations, which might be given the names of historical instances were it not for minor adaptations of circumstances to the present purpose. Suppose that demand for crude oil is increasing; that the price of crude is established economically, i.e., by the costs of marginal producers; that, over a stated time, the increase of demand is supplied from new sources, the costs of whose production are considerably below the costs of the marginal producers;

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[3] W. E. Hubbard: Economics and Well Spacing in Texas. *Trans.* A.I.M.E. (1937) **213**, 167.

and that, therefore, the new developments are of more than average profitability. From these premises it does not necessarily follow that the new production will be sold at less than the "market" price established by the costs of the marginal producers. Nor does it follow that the more-than-average profits that are yielded will be distributed broadly over our economy as, for example, by investment in productive equipment whose creation provides employment or even by expenditures for consumers goods, which would have the same general economic effect. Interesting possible applications of the profits could be pursued. However, consider another possible sequence of events. Suppose that the area overlying the new prolific discovery is quickly subjected to subdivision; that many leaseholders sink many wells, to a total exceeding the technologically estimated optimum number; that the profitability of the whole development is reduced to mediocrity. Under these premises the general public may not enjoy benefits from the rich discovery in the form of low prices; but a great many persons that were engaged on the overdevelopment would have spendable incomes, which they would not have had under a strictly technical development of the pool. Among them would be the operators, who forced the sharing of the discovery for their own selfish ends, drillers and drilling contractors, manufacturers of pipe and fittings, railroads and other transportation agencies that moved the tangible parts of the development to location, and many others.

The Dilemma

It is fully recognized that whatever part of a plant development is technologically excessive is a species of waste. Judged by a too simple standard, the immediate result of all duplicatory effort is waste. The indictment against excessive drilling might include a demonstration of the thesis that (besides useless manual labor) certain natural resources—for example, the ingredients of pipe and fittings, which some day may be required for essential purposes—have been consumed unnecessarily. But this is a superficial view of the matter. It is easier to see and measure the direct cost of allegedly wasteful duplicatory effort than it is to conceive useful employment for it. What would the operators and the associated and supplementary workers have done if they had not been engaged in the development said to be excessive? Probably they would have been idle, not knowing how otherwise to use their energies, and, in terms of economic production, idleness is also waste. In the end, the measurement of the difference between the social waste of overdevelopment and the social waste of idleness is difficult because of its insignificance.

On the other hand, benefits resulting from the widespread distribution of the proceeds of a rich discovery (generally only rich discoveries are overdeveloped) may be far-reaching. In any event, a whole train of equalizing effects is initiated: Potential workers are employed, merchants and utilities are patronized and even demand for the commodity for whose production excessive facilities have been created may be greater than it would have been had the proceeds been more closely controlled under a program of restricted development.

The conclusion to which all these facts is leading must be surmised. Perhaps the term "dilemma" would be more appropriate than "conclusion" because it is assumed that the waste of labor and materials in avoidable duplicatory development and the waste, through idleness, of the particular groups of potential workers that might have been employed on the development, are equally abhorrent.

It is axiomatic that operators would not undertake duplicatory development if more profitable opportunities for investment of their capital were available. Not less important is the corollary that if all competent persons were usefully employed labor would not be available for excessive developments except under terms of competitive bidding, which would tend to discourage them by reducing incentives. However, even under these conditions, incentives are sometimes so great that superfluous wells are drilled for the purpose of protecting profits from competitive attack or of enlarging them at the expense of others. In the last analysis, such developments are governed by economic considerations. In principle, this aspect of competition resembles that current in the retail marketing of gasoline: Good luck (or judgment) in locations is enjoyed; poor luck suffered; all filling stations draw from a common reservoir of demand; other things being equal or proportionate, the firm that "captures" the largest volumes of demand is the one that has the greatest number of outlets to supply the demand (i.e., draw upon the reservoir). Certain harassed marketers petition legislators for a licensing of stations and restriction in their number.

Freedom to Create Plant Facilities

Complex relationships are involved in these matters, but a little further consideration of them may show more clearly the role that the freedom to create plant facilities plays in maintaining balance in the economy.

Overdevelopment, far from being an economic canker, is the immediate and obvious result of the automatic working of forces to maintain a state of equilibrium in the whole economy. In any human endeavor it costs something to effect balance. In economic affairs, part and sometimes all of the cost is represented by overdevelopment; but it need hardly be argued that it is worth it. The cost to our country of several years of disequilibrium was estimated by the Commissioner of Labor Statistics at $133,000,000,000. That sum would virtually rebuild all the plant and equipment of all the agricultural, mining and manufacturing corporations of the country. The forces that effect a balance through excessive development act in a normal economic way by shifting capital and labor from a state of little or no usefulness to places where the rewards to them are significantly enhanced. Presumably, in this latter state their usefulness also has been increased. The importance of this fact is not diminished by any unfavorable reaction upon the earning power of capital that is supplemented or displaced.

General and continued unemployment of capital and labor must mean that the number and scope of creative ideas is short of the need to employ them at a satisfactory profit, or at the prevailing rates of pay and work time. (Exceptions to the rule may arise out of special governmental intervention, but that is outside the scope of this paper.) Lacking new ideas, capital and labor will be used on old ones, that is, in duplicatory effort, if the profit incentive is present. Otherwise, there will be a grave social problem. Perhaps there is an important alternative—perhaps at such times the need for a general reduction in the hours of labor of all classes is indicated. Disregard of the need for fundamental adjustment precipitates economic and political crises.

Technology and Economics

It has been suggested that overdevelopment is not peculiar to oil fields. Steel, cement, railroads, automobiles, rubber, textiles, drug stores, filling stations and other plant facilities, when judged by the equivalents of the technical standards applied to oil fields, must be considered overdeveloped. Therefore there should be particular reasons for singling out a branch of business representing not more than 1 per cent of the total economy of the country for special legislative limitations while overdevelopments in many other industries are entirely ignored. True, the peculiar nature of the petroleum resource may be offered as a reason. This suggests the possibility of physical waste and the incomplete recovery of the reserve—neither necessarily attributable to excessive development. Finally, the implications of the masterful development of petroleum production technique may be offered as a particular reason for limitation of oil-field development.

During the recent past, the latter aspect of the matter has intrigued the industry's personnel as well as outside students of the subject. In the confusion over the nature of the ultimate control of economic endeavor, many have embraced the philosophy of control based upon engineering abstractions and experiments. While heretofore the extent and number of productive units within the industry were governed by the economics of the situation, it is proposed that hereafter they are to be determined technologically. But if technology is to guarantee profits by the use of some formula that assumes future prices and the constantly changing relationships between costs, yields and values, it is usurping the place of economics, which works effectively but in more subtle ways. Moreover, there is the further danger that an arbitrary technology will be placed in control because practicality requires the adoption of the tenets of one of several schools. Can any school dictate the extent of productive facilities with a greater degree of economic suitability than a price-fixing agency can set the prices of commodities? At present, in the oil business, arbitrary action is of the most flagrant and questionable sort because none of the schools upon which it is founded has had enough experience to demonstrate its theories. Indeed, what are called theories (properly, explanations subject to demonstration) are really only hypotheses; that is, explanations not susceptible of proof because in the demonstration of one explanation the reserve employed for the test has of necessity been depleted so that the conditions of the test cannot be duplicated for the comparative examination of an alternative hypothesis.

Effect of Legislation

Legislative regulation of the development of the facilities of our industries reduces the opportunities for the exercise of ingenuity and is to be classed with price fixing, with the planned economy of farmers and with other arbitrary regulation of economic affairs. The involvements caused by attempts to overcome the technologic difficulties of administration place upon such regulation a serious doubt as to its fitness for grafting onto our system of economy.

This, combined with the technical difficulties of administration, places upon the whole matter a serious question of propriety. The conditions of which overdevelopment is the symptom have been enumerated here in as much detail as space permits, but they merit emphasis because they are the best indicators of the need for broad economic changes. This phase of the subject is difficult of complete exposition in unrestricted space and almost impossible of comprehensible dissertation in narrow compass. But if the limitations of highly simplified premises are acceptable, enough may be presented here to warrant the readers' further consideration of the problem.

Assume a balanced economy. All competent persons are gainfully employed for the full standard work time. Supply of goods and services is in balance with demand; productive equipment is in balance with supply. Suppose that the ideas of inventors for the reduction of costs of existing processes run far ahead of creative job-making ideas involving new commodities and services. (The matter will be further simplified if the latter class of inventions is considered nil.) Unit *a* in industry *A* invents a labor-saving machine. It replaces existing equipment and releases a number of former employees. In looking about for livelihoods, they search out the most profitable businesses. Some would build bakeries, others operate retail stores, but in the economy, which, before the invention of the low-cost process, has been balanced, there are enough of these. State regulation prohibits more. Soon, unit *a* in industry *A*, with its lower cost of production, finds its profits accumulating. It desires to expand. It could capture a much larger share of the market by lowering its prices, but the capacity of the industry is equal to demand; even the increased demand potentially possible at the lower prices may be partly offset by the reduction in demand due to the lack of purchasing power of the persons released.

Suppose that simultaneously the same sequence of events occurred in units of other industries. Unemployment would be multiplied. A relief problem would be created. Sooner or later, the bars would have to be let down. The unemployed would gain permission to enter the most profitable industries even at the cost of duplication of effort. The standard of work time for all persons would have to be reduced to the end that the unemployed could be reabsorbed by industry. But a unit that reduced its hours would increase its costs in comparison with those of competitors and would jeopardize its life. Or if the inventive unit reduced its hours to retain its employees, it would gain little from its invention. Inventions of this sort would thereby be discouraged. It must wait for joint action. Who is to set the new standard?

Conclusion

The Secretary of Agriculture does not seem to have learned to substitute technologic control for economic control, though he has had the conservation argument and the resources of the Federal Government to support him, including the power to tax the rest of us hundreds of millions of dollars each year in an effort to make the experiment work. We have not learned either. It is doubtful whether we can succeed any better. In the end, our efforts to replace economics by technology only invite experiments in arbitrary control where the conservation argument is absent. Indeed, already the matter is so far out of hand and the cries for the restriction of competition are so insistent that many persons, including some professional economists, have begun to think that there is no useful competition in business and that thoroughgoing government regulation of business is a necessity. Perhaps the time is ripe to consider the role played by the exercise of freedom to create plant facilities in maintaining equilibrium in the economy and in promoting material progress.

Factors Affecting the Refiner's Choice of Crudes

By G. A. Beiswenger*

(Galveston Meeting, October 1939)

The application of the law of supply and demand to the sale of crude oil is generally conceded, but the motives underlying the buyer's (refiner's) demands are not always obvious to the seller (producer). In some cases this obscurity has led to the conclusion that the refiner may be unnecessarily particular when he selects one crude and rejects another. This preference, however, is very largely the reflection of the refiner's product demands and the quality of the stocks obtainable from the selected crude. The purpose of this paper is to point out critical characteristics of the major classes of refined products and to show how crudes vary in their suitability for such products.

With relatively few exceptions, available processing methods and addition agents make it theoretically possible to produce any type of refined product from any crude source, although it may not be economically sound to do so. The widespread application of thermal cracking for converting higher boiling stocks into gasoline is well known. More recently cracking and refining in the presence of catalysts[9] have been developed, as well as various processes for polymerizing lighter hydrocarbons into gasolines having desirable characteristics.[6] For several years, selective solvents have been applied commercially to refining inferior quality kerosene, Diesel fuel and lubricating oil distillates.[3] Improved methods for refining lubricating oils from crude residua,[4] formerly suitable only for fuel, are now in use and a number of special solvent processes are available for dewaxing lubricating oils to low pour point.[5] These improved refining methods have been developed not only to meet the demand for improved product quality but also to enable the refiner to obtain quality products from crude sources that would not yield such products by the older refining methods.

In many cases, the utilization of these modern refining tools necessitates an appreciable expenditure for equipment as well as added manufacturing costs, and their application therefore must be justified economically. Despite the availability of such tools, the added processing costs involved and yields obtainable may render their application entirely impractical. To illustrate this point, inspections of typical cuts from various crudes

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[9] References are at the end of the paper.

are shown in Table 1. Crude of the *L* type produces kerosene distillate of very high quality; crude of the *I* type produces a cut that can be extracted readily with selective solvents to give good yields of high-quality kerosene. Crudes *D* and *E* yield distillates that can be improved to the same quality level only by excessive extraction and with appreciable loss in yield, while from crude of type *A* it is possible to obtain high-quality kerosene only by exhaustive hydrogenation. Thus, there is a practical limit to which high-quality products can be produced from inferior feed stocks and, obviously, the added costs involved can be justified only if sufficient crude of the *L* type is not available, or if its price is too high.

In view of the marked differences in the characteristics of products from various crudes, it is common practice for the refiner to analyze the crudes available to him. In addition to the usual physical tests, such analyses usually include a complete small-scale distillation of the crude into typical products plus inspections of these products. The results of these analyses permit the refiner to make a proper selection of crudes in accordance with the processing equipment that he has available and his immediate product requirements, and to determine what changes in refining equipment are desirable with regard to future operations. Some of the data from typical analyses of different types of crudes are presented in Table 1. The differences in yield and quality of various fractions are particularly striking. For example, the yield of maximum prime-cut naphtha varies from 6 to 33 per cent and the octane number from 45 to 72. The yield of potential Diesel fuels varies from 10 to 50 per cent, the sulphur content from 0.04 to 2.2 per cent, the pour point from minus 60°F. to plus 5°F., and the Diesel index from 30 to 72. Lubricating-oil distillates vary from below 0°F. to 115°F. in pour point, and from minus 60 to plus 95 in viscosity index on products dewaxed to a pour point of 0°F. It should be observed that these wide differences are not necessarily indicated by changes in the gravity of the crude. For example, although crude *F* is 3°A.P.I. lower in gravity than crude *A*, the latter contains very large quantities of stock of low paraffinicity in the boiling range of kerosene and Diesel fuel, whereas the former contains small quantities of stock of relatively high paraffinicity in the same range.

In order to appreciate the significance of the properties of the various types of crude referred to above, which dictate the selection of one instead of another, it is essential to consider the critical characteristics of the major classes of refined products.

GASOLINES

During the past decade, there has been marked improvement in the quality of automotive gasolines, primarily with regard to: (1) high octane

TABLE 1.—*Quality of Products Obtainable from Various Crudes*

Crude	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*
Gravity, deg. A.P.I.	25.0	28.5	37.0	29.5	32.5	22.0	12.5	42.5	39.0	36.5	41.0	43.0
Normal prime-cut naphtha:												
Yield, per cent[a]	10.0	15.0	31.0	22.0	28.0	12.0	6.0	30.0	33.0	29.0	33.0	32.0
Octane No., C.F.R.-M.M.	72.0	62.0	60.5	61.0	54.0	50.0	56.0	48.0	58.0	50.0	50.0	45.0
Aviation gasoline:												
Yield, per cent[a]	2.0	4.0	10.0	6.5								
Octane No., C.F.R.-M.M.		74.0	73.0	74.0								
Suitability	Yield too low	Good	Fair	Good								
Kerosene or tractor fuel:												
Yield, per cent[a]	26.0[b]	16.0		21.0	21.0	13.0		42.0	23.0	21.0	19.0	23.0
Gravity, deg. A.P.I.	35.0	39.0		40.0	40.6	42.8		43.9	42.2	43.8	44.4	47.2
Sulphur content, per cent	0.06	0.10		0.50	0.46	0.31		0.03	0.04	0.10	0.14	0.04
Sourness	Sweet	Sweet		Very sour	Very sour	Sweet		Sweet	Sweet	Sweet	Sour	Sweet
Thermoviscosity				380	370	380		390	380	300	360	350
Smoke point, I.P.T.					20.0			23.0	21.0	24.0	24.0	30.0
Octane No., C.F.R.-M.M.	65.0	53.0										
Suitability	Good	Fair	Require solvent extraction			Satisfactory except for sulphur		Good	Fair	Good	Satisfactory except for color and sulphur	Very good
Diesel fuel:												
Yield, per cent[a,c]	50.0	29.0	32.0	20.0	19.0	14.0	10.0	41.0	19.0	18.0	17.0	20.0
Gravity, deg. A.P.I.	26.0	29.0	33.0	34.0	35.0	37.0	30.0	39.0	37.0	38.0	40.0	42.0
Sulphur content, per cent	0.18	0.23	0.04	0.8	0.8	0.7	2.2	0.06	0.07	0.20	0.23	0.05
Pour point, deg. F.	−60	−60	−10	−25	−15	−5		0	0	0	0	5
Diesel index	30.0	35.0	46.0	46.0	49.0	56.0	36.0	65.0	59.0	60.0	65.0	72.0
Suitability	Very low grade	Poor but low pour	Fair Diesel index and fairly low pour			Good	Sulphur high	Good quality although somewhat waxy			Good quality but sour	Excellent quality somewhat waxy

TABLE 1.—(*Continued*)

Crude	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*
Lubricating-oil distillates:												
S.U.V. at 100°F.	1000	1000	500	500	500	500			500	500	500	500
Gravity, deg. A.P.I.	17.0	20.0	24.0	22.0	22.0	23.0			25.0	25.0	28.0	30.0
Pour point, deg. F.		0	110	25	90	110			115	100	115	100
Sulphur content, per cent.	0.23	0.42	0.25	1.7	1.9	2.9			0.56	0.80	0.75	0.15
Viscosity index (after dewaxing to 0°F. pour point)	−60	15.0	50.0	45.0	50.0	55.0			55.0	60.0	80.0	95.0
Suitability	Unsatisfactory	Good L.C.T. and Black oils	Unsatisfactory "paraffinic"	High pour for L.C.T. oils	Unsatisfactory "paraffinic"	Low quality "paraffinic"	Unsatisfactory	Low quality "paraffinic"	Low quality "paraffinic"	Fair quality "paraffinic"	Good quality "paraffinic"	Excellent quality "paraffinic"
Asphalts:												
Yield, per cent[d]		5.0	Negligible	11.0	11.0	40.0	65.0	Negligible		7.0	<5.0	Very low
Temperature susceptibility				Fair	Fair	Good	Good			Fair		
Ductility at low temperature				Fair	Fair	Poor	Good			Fair		
Wax content				Satisfactory	Satisfactory	High	Low		Very high	Satisfactory		
Emulsifying characteristics				Poor	Poor	Satisfactory	Excellent			Fair		
Foaming characteristics				Poor	Poor	Poor	Excellent			Fair		
Weathering characteristics				Fair	Fair	Good	Good			Good		
Stain test				Poor	Poor	Poor	Excellent			Good		
Softening point-penetration relationship				Satisfactory	Satisfactory	Satisfactory	Requires blending			Satisfactory		

[a] Normal maximum yield of indicated product. Since the naphtha, tractor fuel or refined oil and Diesel fuel overlap each other consecutive cuts are appreciably less than indicated.

[b] When cutting tractor fuel of 500°F. final boiling point. Refined oil cuts are of 530°F. final boiling point.

[c] Of 650°F. final boiling point and 35 Saybolt universal viscosity at 100°F.

[d] Based on approximately 115°F. softening point asphalt.

number, which has permitted increased compression ratios and consequently greater power, (2) increased volatility, which results in quicker starting and a shorter warm-up period, and (3) lower vapor pressure, which eliminates vapor lock with its attendant irregular operation and stalling in hot weather. Increased volatility is due largely to the adoption of reforming or thermally cracking prime-cut heavy naphtha. Although reforming also increases octane number, in general the octane level obtainable by reforming as well as by improved cracking of heavier distillate and residual stocks has not been sufficiently high to keep pace with the demands of modern motors. This deficiency has been met in most cases by the addition of lead tetraethyl.[8] As mentioned above, the more recent developments in this field include catalytic cracking and polymerization.[9] The use of these processing methods increases the yield of gasoline obtainable from a barrel of crude and also permits the production of gasoline of high octane number from practically any crude source. Although the yield of motor gasoline is increased, the over-all reduction in crude demand will probably not be as great as might at first be assumed when considering this one product since (1) approximately half of the total gasoline production comprises prime-cut naphtha with or without reforming and (2) requirements for other products such as refined oil, heating oils, lubricating oils, asphalts, etc., will not be affected. For the production of gasolines and naphthas other than automotive grades, however, the selection of particular crudes is important.

For aviation gasolines, it is necessary to have low-boiling prime-cut fractions of high octane number. The grade in greatest demand requires a 74 A.S.T.M. octane number before the addition of lead tetraethyl. Cracked stocks generally are not utilized for aviation gasolines and the use of blending agents to improve poorer quality stocks is usually not justified. Hydrogenation[7] of selected fractions is in use for the production of aviation gasolines and the recent development of processes for making iso-octane commercially have facilitated the production of 100-octane aviation gasoline,[10] which is being used in both military and commercial planes. This extremely high octane number product may contain, in addition to normal aviation gasoline and iso-octane, aromatics obtained by solvent extraction from prime-cut naphthas of high aromatic content,[12] and iso-pentane obtained by very efficient fractionation of segregated field casinghead.[13] Table 1 indicates that crudes of the *B*, *C* and *D* type are suitable for the production of aviation gasoline while crude *A* produces prime-cut naphtha of exceptionally high octane number but the yield is relatively low.

A second group of special naphthas comprises the many different types of solvents. These products, in general, must be of good color and exceptionally good odor. Crudes vary decidedly with respect to the latter characteristic, and improvement by other than conventional finishing is impractical. Furthermore, there is a quality distinction in these products in regard to solvent power. Solvents composed largely of aromatic compounds, such as toluene and xylenes, are particularly suitable for use as high-grade lacquer solvents because of their high Kauri butanol value and smooth evaporation curve.[12] Like the blending agent for aviation gasoline, they are produced by selective extraction from prime-cut naphtha of high aromatic content.

KEROSENES AND TRACTOR FUELS

Next higher in boiling range above the naphthas are kerosenes and tractor fuels or heavy distillates for spark ignition engines. For high-quality kerosene, relatively paraffinic fractions that have a low octane number are required; while for the better grade of tractor fuels, prime-cut fractions of relatively high octane number are necessary. Because of the shortage of suitable stocks, extraction with liquid sulphur dioxide (Edeleanu process)[2] has been used extensively in California and to some extent in the Gulf area. The raffinate or undissolved fraction from this process furnishes high-grade refined oil, while the extract or dissolved fraction can be used to improve the octane number of tractor fuel. In addition to paraffinicity, which is indicative of burning quality as measured by smoke point, it is also important that kerosene distillates have good color stability and low sulphur content. Range oil is the product supplied for many types of range burners and does not require the high smoke point (burning quality) necessary in illuminating oil.

Typical inspections on tractor fuel, range oil, and high-grade burning oil at one refinery are shown in Table 2. The variation in gravity between the different products is a rough indication of paraffinicity.

TABLE 2.—*Typical Inspections of Fuels*

	Gravity, Deg. A.P.I.	Sulphur, Per Cent	Color, Saybolt	Thermoviscosity	Smoke Point	Octane Number	A.S.T.M. Distillation	
							Per Cent at 392°F.	Final Boiling Point, Deg. F.
Tractor fuel, high octane number	39.0	0.15				56	58	500
Range oil	43.0	0.07	25	400	23	(20)	28	530
High-grade kerosene	46.0	0.05	25	370	30	(5)	32	530

It should be kept in mind that decided variations in these and the following inspections of trade gas oils exist in different localities because of differences in available crude supplies and in types of fuel-consuming appliances in use.

TRADE GAS OILS

Products in the next higher boiling range are the so-called trade gas oils, and include domestic heating oils, Diesel fuels, gas-enrichment oils, etc. Typical inspections of products from one refinery are shown in Table 3. Heating oil, as given in Table 3, fully satisfies the requirements of automatic domestic burners and can be made from most types of crude. Diesel fuels may be divided into two major groups, depending upon the type of engine in which they are used: (1) high-speed engines for use primarily in trucks and tractors and (2) slow-speed engines for power generation or marine propulsion. The high-speed engine requires a high or medium quality fuel,[11] as shown in Table 3, which has a fair degree of paraffinicity and reasonably low pour point. In addition, it is desirable that it be low in organic acidity and relatively sweet; i.e., practically free from malodorous mercaptans.

TABLE 3.—*Typical Inspections, Trade Gas Oils*

	Gravity, Deg. A.P.I.	Flash Point, Deg. F.	Pour Point, Deg. F.	Sulphur, Per Cent	Diesel Index	Saybolt Univ. Viscosity, 100°F.	A.S.T.M. Distillation	
							Per Cent at 440°F.	Final Boiling Point, Deg. F.
Heating oil	33.0	160	0	0.6	40	33	20	615
High-quality Diesel fuel	37.0	170	0	0.3	57	35	10	645
Medium-quality Diesel fuel	33.0	170	0	0.6	48	38	6	700
Marine Diesel fuel	22.3	155		0.2	30	70		

From the standpoint of ignition quality, fuels for slow-speed Diesel engines do not need to be as paraffinic and are usually composed of high-boiling distillates from crudes of low paraffinicity or whole or reduced crude, depending largely upon the type of installation. An important example from the large group of miscellaneous gas oils is the so-called low-sulphur gas oil. This product is required where the presence of sulphur in the products of combustion is detrimental, as in the annealing of copper and brass products and in the ceramic industry.

LUBRICATING OILS

Lubricating oils constitute one of the most diversified and exacting groups of petroleum products in so far as crude selection is concerned. From the viewpoint of crude source, lubricating oils may be classified as "low cold test" and "paraffinic." The low cold test oils are produced from crudes containing practically no wax, which obviously demands careful segregation. It is desirable to have a pour point below 0°F. and only a slight haze at temperatures around 32°F. on oils up to a viscosity of approximately 1000 Saybolt seconds at 100°F. (kinematic viscosity of 220 centistokes). If the crude is properly segregated, dewaxing of oils below approximately 1000 Saybolt seconds at 100°F. is unnecessary. Dewaxing may be required, however, on the more viscous oils, oils from crudes containing small amounts of wax, or, on products refined to a higher quality by extraction or hydrogenation, which tends to increase the cloud and pour points. The viscosity index,[1] or measure of change in viscosity with temperature, of unfinished low cold test oils is usually in the range of 10 to 40. Other critical characteristics include solvency for compounding agents, exceptionally low or high sulphur content, and low A.P.I. gravity or high specific gravity. Because of the limited amount of processing necessary, low cold test oils are usually cheaper than paraffinic oils. However, their specific characteristics are advantageous in many types of service. Since distillates of the low cold test type vary considerably in respect to these critical characteristics, it is apparent that careful selection of crudes must be made if satisfactory products of all types are to be manufactured.

All lubricating oil stocks of the paraffinic type are high in pour point and for most uses must be dewaxed. This costly processing operation can be justified because many of the waxes are valuable by-products and the paraffinic lubricants are considered to be superior for many purposes. The degree of paraffinicity is conveniently expressed in terms of viscosity index, which may vary from about 50 to 100 or even higher. For automotive and aviation engines, high viscosity index and resistance to oxidation and sludge formation are very important. Similarly, stability of an oil under service conditions is required in many industrial lubricants; for example, turbine oils. Table 1 indicates that lubricants from *L* type crude would be of superior quality while those from *K* are also of good quality. Paraffinic lubes of only fair quality are present in crudes of the type of *F*, *I* and *J*. It is well known, of course, that the latter can be refined by solvent extraction[3] or hydrogenation[7] to give a viscosity index of 100 or even higher with accompanying improvement in stability toward oxidation and sludge formation. As with refined oils, however, this requires additional processing and hence added manufacturing costs and entails a loss in yield varying with the quality of the feed stock.

It will also be noticed that the residuals from certain crudes such as *B*, *J*, *K* and *L* have very low asphalt content. Residuals from a low cold test crude (e.g., *B*) find some application as black oils. Residuals from *L* type crude are suitable for steam-cylinder lubrication and can be refined by conventional methods to givc highly paraffinic, viscous lubricants. To produce high-quality lubricants from crude bottoms of the *B*, *J* and *K* type, however, requires special processing. The preferred method is to precipitate the asphaltic material from the desired lubricating-oil constituents by means of propane or other light hydrocarbons, either with or without acid treatment or selective solvent extraction in propane solution.[4] Crude residuals containing as much as 50 per cent asphaltic material have been handled commercially by these methods.

It would appear that with solvent extraction, solvent dewaxing and propane refining processes at his command, the refiner of lubricating oils would be independent of crude source. In addition to the added manufacturing costs, however, the performance of the finished product in actual service must be considered. Starting with two feed stocks of the same viscosity index and applying identical refining procedures to manufacture two products having substantially the same physical tests, it has been found that the finished products may not exhibit identical performance characteristics. For reasons not clearly defined but probably depending upon variations in chemical composition, finished lubricants from certain crudes are markedly superior for specific services. Thus the refiner of lubricating oils attempts to select those crudes that will give not only the best yields of finished products meeting his particular specifications but also the best performance in actual service.

ASPHALTS

Asphalt products are of two primary types, depending upon whether they are used for (1) paving or (2) roofing. Principal requirements for the paving grades are good susceptibility or minimum change in consistency with temperature, good ductility at normal as well as low temperatures in order to prevent cracking during the winter, and relatively low wax content. In addition, those asphalts that are applied as emulsions must be susceptible to emulsification by normal procedures. Besides these chief characteristics that affect the suitability of asphalts for paving purposes, specifications are drawn up by many customers in such a manner as to require definite crudes for their manufacture. These limitations are usually imposed by specifying very narrow susceptibility ranges and minimum ductilities, gravities, and asphaltene contents.

The roofing grades include fluxes used to saturate roofing felt and the corresponding coating asphalts produced by oxidizing these fluxes. Fluxes must not foam excessively when the felt, containing appreciable moisture, is dipped into the heated flux. The oxidized coating asphalts must have a suitable softening point-penetration relationship, must not discolor the granules used for surfacing the roofing material, and must weather satisfactorily.

Table 1 shows that crudes *F* and *G* give exceptionally large yields of asphalts. Those from the former crude are suitable for paving grades, while the quality of asphalts from the latter crude is excellent in all respects. Crude *J* has been extensively used for the manufacture of asphalts of the roofing type. Crudes *D* and *E* also give appreciable yields of asphalts but the quality is relatively poor. It is apparent that the refiner possessing sizable outlets for asphalt products must have available crudes that will give good yields of the specific grades required.

General

With a knowledge of his manufacturing facilities, product requirements and detailed analyses of crudes available to him, the refiner can intelligently prepare his running schedule. For example, if there is a large demand for high octane number tractor fuel, it will be necessary to obtain crude of the *A* or *B* type. If a choice between these two types were possible, the decision should depend upon the magnitude of his requirements for low cold test lubricating oils. If the refiner were running appreciable quantities of type *L* crude for highly paraffinic lubricating oils, he could consider type *F* for the production of paving asphalts plus type *I* to help overcome the high sulphur content of the refined oil from *F* crude and also to increase his supplies of trade gas oils. Crude *J* could conceivably give a satisfactorily balanced production for a refiner requiring kerosene, trade gas oils, average quality paraffinic lubricants and roofing asphalts but no high octane number tractor fuel or low cold test lubricants. If the refiner required aviation gasoline and additional motor gasoline production, crude of the *D* type might be highly desirable, although he would be faced with the high sulphur content and sourness of the gasolines. It is apparent that a very large number of combinations is possible. In many sections of the country, large volumes of the specific products covered above are cracked to gasoline, since the crudes available in those sections contain quantities of these products far in excess of the tributary outlet. For example, crudes in the Upper Mississippi Basin yield an oversupply of refined oil, while on the Pacific Coast the opposite is true.

The present discussion has been confined to principles of crude selection based on the yields and quality of the products obtainable therefrom, with only passing mention of processing costs involved, as distinguished from price factors. The latter involve comprehensive economic analyses beyond the scope of this paper. In addition to the principles of selection set forth above, the refiner's ultimate choice of certain crudes and rejection of others must of necessity also include the question of price.

References

1. E. W. Dean and G. H. B. Davis: *Chem. and Met.* (1929) **36**, 618.
2. A. E. Dunstan, A. W. Nash, B. T. Brooks and H. T. Tizard: The Science of Petroleum, **3**, 1888.
3. *Ibid.*, 1893, 1904, 1910, 1915, 1918.
4. *Ibid.*, 1924, 1966.
5. *Ibid.*, 1945, 1962, 1966.

6. *Ibid.*, 2045.
7. *Ibid.*, 2139.
8. L. E. Hebl, T. B. Rendel and E. L. Garton: *Ind. and Eng. Chem.* (1933) **25**, 187.
9. E. Houdry, W. F. Burt, A. W. Pew, Jr. and W. A. Peters, Jr.: *Oil and Gas Jnl.* (1938) **37**, No. 28, 40.
10. W. H. Hubner and G. Egloff: *Oil and Gas Jnl.* (1938) **36**, No. 46, 103.
11. W. H. Hubner, G. B. Murphy and G. Egloff: U. O. P. *Booklet* 228 (1938).
12. A. Saegebarth, A. J. Broggini and E. Steffen: *Nat. Petr. News* (1937) **29**, No. 22, 51.
13. S. D. Turner and A. C. Rubey: *Chem. and Met.* (1938) **45**, 362.

Economic Dynamics of the Domestic Demand for Motor Fuel

By Norman D. Fitz Gerald,* Member A.I.M.E.

(New York Meeting, February 1940)

The growth of domestic requirements for motor fuel has been phenomenal, rising year after year in a fashion almost unique among commodities, resisting depressions and forging rapidly ahead in times of prosperity. Consumption advanced from 226 millions of barrels in 1925 to 522 millions of barrels in 1938; or 130 per cent. The economic influences generating and sustaining this demand are of vital concern to the petroleum industry.

The general factors affecting utilization of motor fuel are well known but it is the purpose of this paper to employ the recently developed technique of economic dynamics to describe them mathematically. Such problems in economic analysis are complicated by the freedom of all the variables to fluctuate, their mutual interdependence, changing incidence upon one another, and the nonquantitative character of some of them. Economic quantities and relationships, unlike those of the physical world, are continuously changing and this dynamic characteristic is both a distinguishing and confusing feature in economic research. The complexities of the problems require application of the analytical devices of mathematical statistics to uncover the probable relationships between factors. The procedure employed is to formulate a logical relationship linking the dependent to the independent variables, and then simultaneously, rather than sequentially, determine their separate effects by multiple correlation. This transformation of common knowledge to quantitative terms makes it possible to measure the probable effects of changing conditions upon requirements, assisting in the sound interpretation of economic policies. The utility of the results of such dynamic analysis is in sharp contrast to the sterility of the trends and other simple empiricisms of descriptive statistics.

It is not intended in this study to throw light on the reasons why any motor fuel at all is consumed; but to discover relationships explaining why more was consumed at one time than at another. Specifically the problem is confined to the measurement of the influences of statistically

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determinate factors governing fluctuations in domestic requirements of motor fuel from 1925–1938. This brusque disposal of fundamental motives underlying human behavior, and the substitution of their outward manifestations in statistical series for reality itself, is not as serious a break in logic as at first it appears to be. For if there are millions of motor vehicles registered in a country, it is certain that highways and fuel are available, while sales of fuel will vary with its price and the incomes of consumers. These deductions are sound, yet none indicates the actual reasons why people feel impelled to move about on the highways. The real motives are far more complicated and diverse than the statistics which serve adequately to measure the characteristics of mass behavior once they become well established. In fact it is often unnecessary purely for purposes of statistical analysis to go beyond the figures unless important social or economic changes are in process which have a direct bearing upon the problem.

Analysis of the Demand-generating Factors

Multitudes of influences are at work determining the expansion and fluctuation of demand for motor fuel. The primary components are the number of motor vehicles registered, price of motor fuel to the consumer, miles of hard-surfaced highways and national income. These factors influence one another but are largely determined by a group of secondary constituents. The ownership of motor vehicles has been stimulated by their rising quality and declining price, further accentuated by the drop in average operating costs. Other contributing elements have been the development of suitable roads, growth of suburban residential areas heavily dependent on motor vehicles, advances in winter-time utility of cars, increasing leisure, multiplication of logical objectives for travel, and the opening of motor camps and inexpensive restaurants along the highways. The net resultant of these and many other influences bearing on motor-fuel demand appears to be adequately expressed by the factors represented statistically in the following series, shown in Fig. 1:

D = annual domestic demand for motor fuel, millions of barrels (U. S. Bureau of Mines).

R = millions of registered motor vehicles (Automobile Manufacturers Association).

P = average price of motor fuel to consumers in 50 cities, cents per gallon tax included (American Petroleum Industries Committee).

HT = thousands of miles of hard-surfaced highways, partly estimated, represented by H (U. S. Bureau of Public Roads). The number of years from 1924, represented by T as a multplier.

N = national income, billions of dollars (U. S. Department of Agriculture).

The most important of these components is the number of motor vehicles registered, and the others operate upon this basic one as modifying influences. Highway mileage is a smoothly changing factor of minor importance and for simplicity the number of variables employed in the study has been reduced by including the time element as a multiplier. Motor fuel is not consumed by registered motor vehicles but by cars actually in use, and while the cost of fuel is a major variable charge and unduly prominent in the minds of operators, other costs of automotive transportation have a bearing on the use of vehicles. Nevertheless qualitative examinations of these and other considerations in conjunction with the results of the calculations lead to the conclusions that the errors introduced by disregarding them are small and compensating. After the computation of coefficients by the methods of multiple correlation, the equation derived for relating the domestic demand for motor fuel to the several elements is as follows:

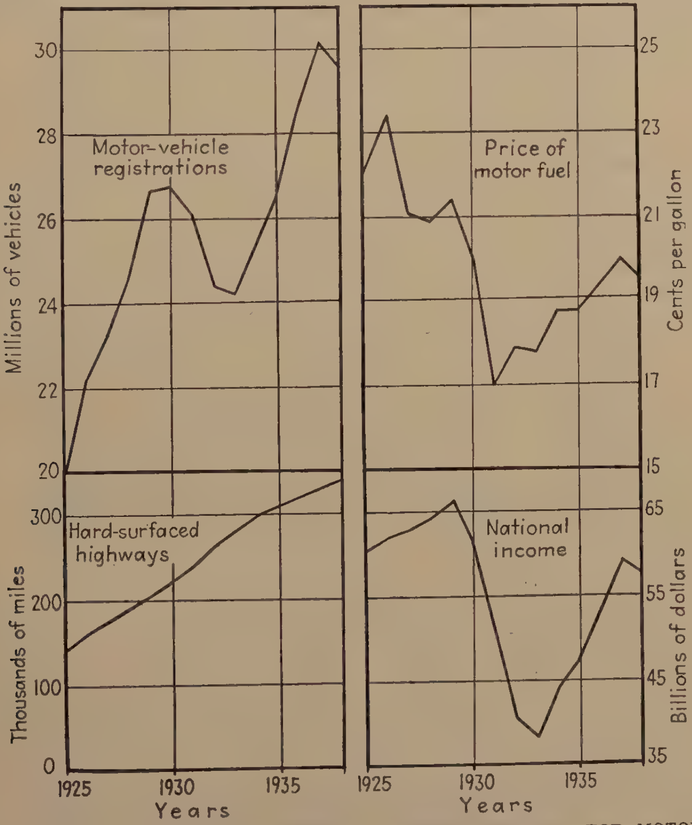

FIG. 1.—MAJOR FACTORS INFLUENCING DOMESTIC DEMANDS FOR MOTOR FUEL (ANNUALLY, 1925–1938).

$$D = 17.865R - 7.199P + 0.023HT + 0.409N$$

SIGNIFICANCE OF THE ANALYSIS

This equation represents the combined influences of the major factors upon the domestic demand for motor fuel during the period 1925 to 1938. The conformance of the actual data and the estimates is good, as shown in Fig. 2, especially when the accuracy of the statistics and the nature of the forces at work are considered. The average error is only one-fourth of one per cent, and the corrected coefficient of multiple correlation is 0.999, in a large measure justifying the selection of constituents and their modes of expression. Equations representing the separate effects of each component upon demand are derived from the original one by introducing the mean values of other independent variables. The resulting formulas are shown graphically in Fig. 3, and are listed in Table 1 with the effects of each factor in the total determination and in the variation of demand as derived from the correlation analysis.

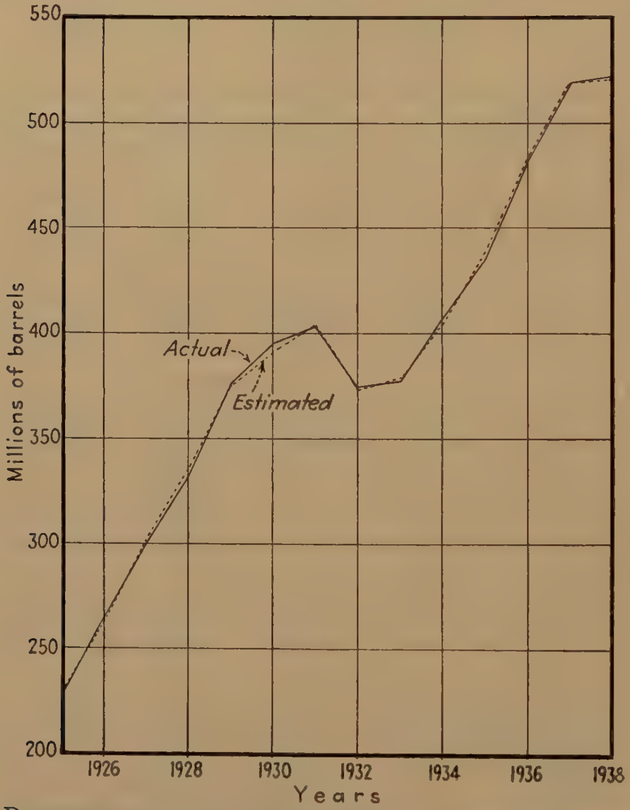

FIG. 2.—DOMESTIC DEMANDS FOR MOTOR FUEL AND ESTIMATES FROM RELATED STATISTICAL SERIES (ANNUALLY, 1925–1938).

The only one of these demand-generating elements over which the industry has a measure of control is that of price. The decline in motor-fuel prices has been an important influence for it has enlarged demand directly through expanding unit consumption and indirectly through increasing the ownership of motor vehicles. During the past 20 years the price of motor fuel to consumers has been characterized by a persistent decline, which terminated with the great depression. The price

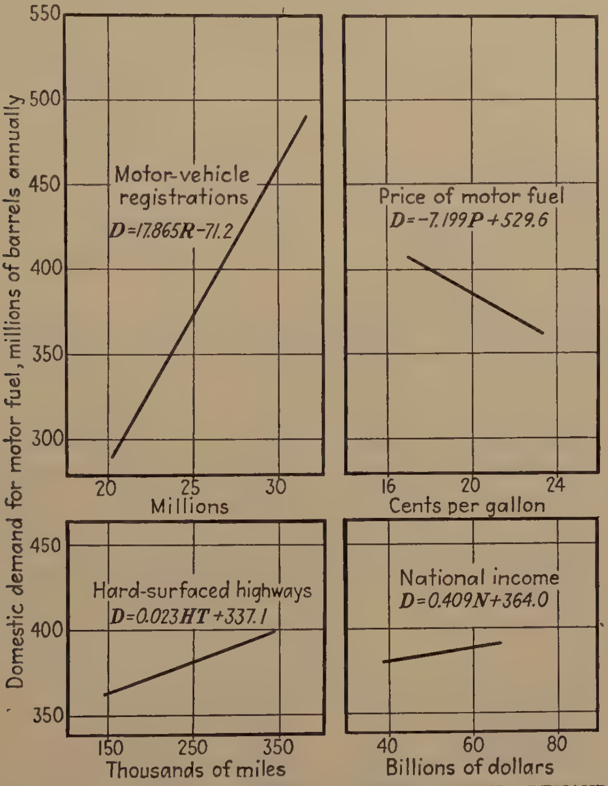

FIG. 3.—INFLUENCES OF MAJOR FACTORS ON THE DOMESTIC DEMAND FOR MOTOR FUEL (AVERAGE, 1925–1938).

TABLE 1.—*Formulas*

Factors	Equations Showing Separate Influences of Factor on Demand	Percentage Weight of Factor in Total Determination as Derived from Analysis	Percentage Change in Demand for a One Per Cent Change in the Factor as Derived from Analysis
Motor vehicles registered.	$D = 17.865R - 71.2$	68	+1.18
Price of motor fuel.......	$D = -7.199P + 529.6$	21	−0.37
Highways and trend.....	$D = 0.023HT + 337.1$	8	+0.13
National income.........	$D = 0.409N + 364.0$	3	+0.06

of motor fuel, ex-tax, has continued to decline but in recent years the advance in tax has exceeded the drop in price. These data are shown by five-year periods in Table 2.

TABLE 2.—*Average Price of Motor Fuel and Tax in Fifty Cities*
CENTS PER GALLON

Years	Price (Ex-tax)	Tax	Price (Tax Included)	Change, Per Cent
1919–1923	25.43	0.33	25.76	
1924–1928	19.34	2.37	21.71	−15.7
1929–1933	14.56	4.27	18.83	−13.3
1934–1938	13.99	5.33	19.32	+ 2.6

There are far-reaching implications in this transition from a declining to a stable or advancing price for motor fuel because lower prices have been an important factor in the rapid expansion of demand through stimulating sales to consumers with lower incomes. This impetus to growth has now virtually disappeared, or perhaps reversed, as future price levels are not likely to be much lower than those of the recent past. For it is not to be expected that technologic achievements can continue indefinitely to lower total costs despite the deeper horizons that must be tapped for crude supplies and the improved qualities required in motor fuel. The industry passes its savings promptly along to consumers and so in a measure has expanded requirements. On the average, however, a general reduction of 1 per cent in the price of motor fuel may be expected to have a direct effect in raising consumption of only about 0.37 per cent; which is the elasticity of demand with respect to price. When this coefficient is less than one, the increase in volume accompanying a reduction in price is gained at a loss of gross income from sales of the product. Therefore cutting prices below normal levels without a corresponding reduction in cost would be impractical and economically unstable. For the period 1925–1938, elasticity of demand for motor fuel averaged 0.37, but it declined from 0.46 in the half period 1925–1931, when prices averaged 20.9¢ per gallon to 0.30 in the half period 1932–1938, when prices averaged 18.9¢ per gallon. If consideration is given to the inflexibility of the tax the average effective elasticity of demand is reduced from 0.37 to 0.34.

This low effective elasticity of demand combined with the rather uniform character of the products of the major suppliers is the genesis of some of the intense and vicious competition in marketing. A short-lived reduction in prices does little to stimulate demand but is a major controlling influence in shifting it from one seller to another without appreciably increasing the total amount of business. The re-establishment of the equilibriums of price and distribution of volume under such conditions is peculiarly difficult.

CONCLUSIONS

The major factors affecting the domestic demand for motor fuel have been formulated, weighed, and presented in a mathematical expression standing the tests of reason and opening the way for further investigations in petroleum economics. It has been established that although the most essential item in determining consumption of motor fuel is the number of motor vehicles registered, price is a prime consideration, while minor roles are played by the mileage of hard-surfaced highways and national income. Demand is also encouraged by certain nonquantitative elements, which have not been included in this study, such as more comfortable cars, better roads, decentralization of industries, and increasing leisure. In all probability these and other factors will combine to augment domestic motor-fuel requirements as registrations mount toward the inevitable though distant saturation level, the proportion of heavy units such as trucks and buses rises, the web of highways expands, and as consumption in the air, on water, on farms and for nonautomotive purposes increases. However, it should not be overlooked that shifts in economic balance or technology such as important changes in costs, standards of living, efficiencies of internal-combustion engines, sources of energy, or alterations in the socio-economic structure of the country might supervene and accentuate or stunt the growth of demand or distort the relationships now regarded as normal.

DISCUSSION

(Lyon F. Terry presiding)

M. WATSON,* Berkeley, Calif.—Dr. Fitz Gerald has made a valuable study, which should be of great interest to the petroleum industry generally and to gasoline marketers in particular. The use of modern statistical methods is well advanced in the analysis of demand for many commodities, especially those sold under relatively "pure" competition, such as farm products in wholesale markets. Much of the pioneer work in statistical demand analysis has been confined to the agricultural field, because there has been a great deal of research inspired by the agricultural departments of the Federal Government and the various state educational institutions. Furthermore, great quantities of data have been assembled in order that such analyses could be made.

The extension of these analytical techniques to industrial product selling is limited often by lack of reliable data on prices and sales. The oil industry, however, finds its heavy tax burden has a slight advantage in that gasoline-tax reports have been made available and these offer a reasonably accurate measurement of sales of motor fuel, or quantities demanded. Few industries have such complete sales data.

The method of multiple correlation is commonly used to measure the effect of variance in factors thought to affect volume of sales, with variations in sales volume.

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Taken singly, the net effect of each factor is much obscured by the effects of the other factors, so that it is necessary to "hold constant" the effects of all other factors, while measuring the "net effect" of each factor in turn. This is essentially what multiple correlation does.

Using this method, Dr. Fitz Gerald computes the net effect of four major factors on demand for gasoline in the United States. The factors he chooses for this analysis combine together in such a way that when each is weighted by its net effect, the additive result is an estimated consumption figure, which agrees very closely with actual sales volume over the past 14 years. Does this prove that the factors chosen are necessarily the causal influences that determine the amounts of motor fuel sold?

Unfortunately, the techniques of statistical analysis cannot prove causality. Covariance, or the property of one numerical series to vary with other series, can be measured accurately by mathematical methods, but the methods do not tell why one series varies with the others, or which is the cause and which the effect, of two series thus compared. Nor do close approximations prove that there are not other factors that may influence the quantities sold. Statistical analysis measures variations, and if there were important factors present during the time this study was made, which did not vary, then their influence has not been included. It is possible that some unlisted factors may have varied in a compensating manner, so that their combined net influence has not been large enough to introduce any important error due to their omission. Lastly, new factors may arise in the future, which are unknown at present. Therefore, Dr. Fitz Gerald's formula should be considered as subject to change as new years are added to his time series. It would be quite exceptional among analyses of time series if this were not so, and it is no reflection on his work. Economic analysis is applied to changing relationships under conditions that are continually changing, and it can never become as precise as the time of relationships in the physical sciences.

In assigning various percentage figures to the factors influencing demand, Dr. Fitz Gerald neglects the high intercorrelation between some of the factors, such as motor-fuel prices and national income. Fig. 1 shows a similarity between the time series of these two factors. Obviously, they share a common influence, which determines their variance to a large extent. If this be so, it seems impossible to arbitrarily say that the price of motor fuel is seven times as important a demand influence as national income. The usual statistical tests of partial or part correlation are not reliable as true indicators of relative importance, when there is high intercorrelation between some of the varying factors. Dr. Fitz Gerald is careful to state that these percentage figures show the weights of each factor, *as derived from the analysis.* The limitations of statistical analysis should be considered in the interpretation of these percentage figures.

The point that demand for motor fuel is highly inelastic is not to be questioned. The lack of substitutes for motor fuel derived from petroleum would indicate that, as well as the experience of the oil industry. It is advisable to have this elasticity measured, and Dr. Fitz Gerald has done that within the limits of his data. Inasmuch as it is impossible for the entire industry deliberately to vary the price of motor fuel in an attempt to measure customer reaction on volume of sales, the only way to obtain the reaction of buyers to price is through the method of statistical analysis.

Dr. Fitz Gerald ascribes some of the intense competition in the marketing of motor fuels to the highly inelastic demand. It is true that short-lived "price wars" do not result in greatly increased total sales. It has been the experience of the writer that such price reductions do not effectively shift patronage from one seller to another, and hence these "price wars" are futile on both counts. Yet they are a common phenomenon in the marketing of motor fuels.

The other side of the situation is well worth mentioning. The same inelasticity that makes price cutting an unprofitable policy operates to reward price maintenance. The larger oil companies appear to appreciate this, but the industry has many smaller marketers who may not concern themselves with the general welfare of the business in which they are engaged. These men are apt to overlook the effect of their sales policies on other marketers, and to operate their businesses much as though demand were infinitely elastic. Herein lies much of the price trouble in the petroleum industry.

Dr. Fitz Gerald's study should point the way toward other statistical analyses of demand. The industry needs additional information on demand elasticities by regions, as it is unlikely that consumers average the same in their reactions to price in all parts of the United States. Agricultural sections could scarcely be expected to have the same demand elasticity as urban districts, since motor fuels are not purchased for the same purposes in the two territories. An intelligent pricing policy would lean toward maintaining somewhat higher prices in sections with more inelastic demand than in districts with more elastic demand. Doubtless marketing executives have found, by trial and error, the sections in which it is most profitable to maintain or attempt to maintain wider margins, but more precise information should be welcome in making these adjustments.

Statistical analysis is a valuable tool in economic studies. Like most valuable tools, this one should be in the hands of men well trained in its use, and in full knowledge of its limitations. Results are then dependable and a foundation is laid for future research. Dr. Fitz Gerald is to be congratulated in laying such a foundation for future work in the analysis of petroleum-marketing problems.

L. F. Terry,* New York, N. Y.—You have found that demand for motor fuel increases at a somewhat higher rate than that for the number of motor vehicles. Is there a simple explanation of this relationship?

N. D. Fitz Gerald.—Increasing demand per unit is due to rising consumption per passenger car and the advancing proportion of trucks and buses.

J. D. Gill,† Philadelphia, Pa.—I should like to express the hearty approval I feel respecting Dr. Fitz Gerald's application of some advance statistical techniques to the analysis of problems of our industry. While I am inclined to think that use of some of the refinements of method may not be warranted because of the character of the data with which they deal and, therefore, because of the results to which they lead, nevertheless it is high time that the best tools of mathematical science and statistical procedure should be brought to bear on our economic studies.

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World Consumption of Petroleum and Related Fuels during 1939

By V. R. Garfias,* R. V. Whetsel,* Members, and J. W. Ristori,* Associate Member A.I.M.E.

(New York Meeting, February 1940)

World consumption of petroleum and related fuels for civil purposes in 1939 was close to 2,024,000,000 bbl., or approximately 110,000,000 bbl. more than in 1938, the United States accounting for 96,000,000 bbl. of the increased amount.

With the annexation of Czechoslovakia and part of Poland, civil consumption in Germany during 1939, notwithstanding severe rationing in the last four months of the year, was 54,000,000 bbl., or only 1,600,000 bbl. less than in 1938, and domestic production of petroleum and related fuels was some 34,000,000 bbl. short of civil consumption. The mounting petroleum requirements of the military forces of greater Germany are, of course, not included in these figures of civil consumption. To supply this deficiency Germany now must rely almost exclusively on the Rumanian fields, which in 1939 produced about 35,000,000 bbl. in excess of the Rumanian civil consumption. However, these fields are supplying and have supplied for years the oil requirements of the neighboring

Table 1.—*World Petroleum Balance Sheet*

Thousands of Barrels

Year	World Production of Petroleum and Related Fuels	World Civil and U. S. Military Consumption	Excess Production over Consumption			United States		Foreign Military Consumption and Additions to Stocks
			United States	Foreign	World Total	Excess Exports over Imports	To Stocks	
1932	1,362,039	1,348,407	R13,011	26,643	13,632	28,781	R41,792	55,424
1933	1,467,128	1,406,923	67,427	R7,222	60,205	60,254	7,173	53,032
1934	1,562,834	1,507,599	26,164	29,071	55,235	64,013	R37,849	93,084
1935	1,702,793	1,614,475	53,027	35,291	88,318	75,474	R22,447	110,765
1936	1,864,997	1,795,560	52,209	17,228	69,437	74,890	R22,681	92,118
1937	2,121,337	1,914,856	161,445	45,036	206,481	115,677	45,768	160,713
1938	2,062,090	1,914,007	130,343	17,740	148,083	139,420	R 9,077	157,160
1939	2,156,700	2,023,883	88,000	44,817	132,817	130,000	R42,000	174,817

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* Cities Service Co., New York, N. Y.

Balkan States and part of the Italian needs, so that all of the excess is not available to Germany.

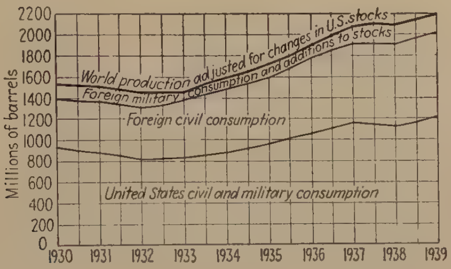

FIG. 1.—WORLD PRODUCTION AND CONSUMPTION OF PETROLEUM AND RELATED FUELS.

Should Italy go to war as an ally of Germany, the available Rumanian supply would be insufficient to meet the requirements of Germany and Italy, even assuming that the Balkan States were entirely deprived of Rumanian oil. These conditions seem to assure the continued neutrality

TABLE 2.—*World Production of Petroleum and Related Fuels*

THOUSANDS OF BARRELS

Country	1938			1939		
	Crude Oil	Related Fuels	Total	Crude Oil	Related Fuels	Total
United States	1,212,970	52,000	1,264,970	1,258,000	52,000	1,310,000
Russia	209,000	1,000	210,000	222,000	1,000	223,000
Venezuela	189,100	900	190,000	199,000	1,000	200,000
Iran	75,000	1,000	76,000	81,000	1,000	82,000
Netherlands East Indies	55,600	2,000	57,600	56,700	2,000	58,700
Rumania	48,500	700	49,200	49,000	1,000	50,000
Mexico	37,000	1,000	38,000	42,000	1,000	43,000
Iraq	30,900		30,900	30,000		30,000
Colombia	21,500	600	22,100	24,300	700	25,000
Germany	4,300	13,000	17,300	5,000	15,000	20,000
Trinidad	17,800	200	18,000	18,700	300	19,000
Argentina	16,300	400	16,700	18,000	400	18,400
Peru	16,000	1,200	17,200	15,000	1,200	16,200
British India	9,860	140	10,000	10,050	150	10,200
Canada	5,000	3,000	8,000	5,100	3,000	8,100
British Borneo	7,180	150	7,330	7,800		7,800
Bahrein Islands	8,480		8,480	7,600		7,600
Egypt	3,820	150	3,970	4,600		4,600
Poland	2,530	150	2,680	3,850	150	4,000
Japan	2,260		2,260	2,900	200	3,100
Ecuador	1,540	60	1,600	2,200		2,200
Others	2,100	7,700	9,800	6,300	7,500	13,800
	1,976,740	85,350	2,062,090	2,069,100	87,600	2,156,700

TABLE 3.—*World Consumption of Petroleum and Related Fuels*[a]

THOUSANDS OF BARRELS

Country	1938						1939					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	523,003	56,360	409,282	21,233	127,245	1,137,123	554,000	60,000	455,000	24,500	139,500	1,233,000
Russia	27,000	42,000	65,000	9,500	21,000	164,500	28,000	44,000	67,000	9,600	22,000	170,600
United Kingdom	47,500	7,000	30,000	3,800	4,500	92,800	46,800	7,000	29,900	2,900	4,400	91,000
Germany	24,900	800	18,700	3,900	7,300	55,600	24,200	800	18,100	3,800	7,100	54,000
Canada	23,000	650	15,500	4,000	4,850	48,000	24,000	700	17,000	4,100	5,000	50,800
France	26,500	1,800	18,300	2,500	4,900	54,000	24,800	1,700	16,900	2,200	4,400	50,000
Argentina	7,000	1,300	17,000	500	1,800	27,600	7,600	1,300	17,500	550	1,900	28,850
Japan	7,800	1,500	11,800	1,800	2,100	25,000	8,000	1,500	12,000	1,800	2,100	25,400
Netherlands West Indies	250	50	17,000	50	5,000	22,350	270	55	17,500	55	5,300	23,180
Italy	5,500	950	11,850	950	1,750	21,000	5,700	1,000	12,200	1,000	1,900	21,800
Mexico	3,000	800	12,600	200	1,400	18,000	3,500	800	12,700	200	1,400	18,600
British India	2,700	7,000	4,100	1,050	1,400	16,250	2,700	7,200	4,200	1,000	1,400	16,500
Rumania	1,000	1,200	10,000	220	1,800	14,220	1,100	1,250	10,500	230	1,900	14,980
Australia	7,800	1,300	3,800	450	1,100	14,450	7,900	1,300	3,900	500	1,150	14,750
Netherlands	3,600	2,000	3,800	450	1,100	10,950	3,900	2,100	4,100	500	1,200	11,800
Netherlands East Indies	1,500	2,000	6,100	250	1,500	11,350	1,500	2,000	6,200	250	1,500	11,450
Iran	600	1,300	5,700	400	2,600	10,600	650	1,300	6,000	450	2,700	11,100
Sweden	4,500	900	3,400	400	700	9,900	4,800	900	3,700	450	800	10,650
Venezuela	1,050	35	7,500	40	300	8,925	1,150	40	8,000	40	300	9,530
Brazil	2,750	850	4,250	250	100	8,200	2,900	900	4,500	280	150	8,730
Union of South Africa	4,100	470	1,700	280	400	6,950	4,300	500	1,800	300	400	7,300
Denmark	2,700	800	2,500	350	200	6,550	2,900	900	2,800	350	250	7,200
Belgium	4,100	350	1,300	400	500	6,650	4,300	350	1,500	350	450	6,950
China	1,300	2,800	1,700	300	400	6,500	1,400	2,900	1,750	300	400	6,750
Egypt	800	1,800	2,800	200	450	6,050	850	2,200	2,900	250	500	6,700
Cuba	750	80	4,200	50	120	5,200	800	100	4,800	60	140	5,900
French West Africa	340	100	4,900	40	10	5,390	400	100	5,200	50	20	5,770
Chile	700	100	4,100	70	50	5,020	750	100	4,300	80	150	5,380
Norway	1,500	400	2,500	130	200	4,730	1,600	400	2,800	130	200	5,130
Trinidad	120	70	4,150	30	350	4,720	140	80	4,400	40	450	5,110
Spain	2,300	180	1,300	100	120	4,000	2,600	200	1,600	160	140	4,700
British Malay	1,000	300	2,900	120	200	4,520	1,000	300	3,000	130	200	4,630
New Zealand	2,550	200	1,300	100	200	4,350	2,400	200	1,400	100	200	4,300
Iraq	350	230	2,400	60	800	3,840	350	250	2,700	60	800	4,160
Hawaiian Islands	1,200	200	2,400	100	100	4,000	1,200	200	2,500	140	100	4,140
Philippine Islands	900	400	2,100	160	130	3,690	1,000	450	2,300	170	140	4,060
Switzerland	1,750	170	1,300	150	100	3,470	1,800	180	1,400	160	100	3 ,640
Poland	800	1,100	600	350	500	3,350	Included in Germany and Russia					
Colombia	800	130	1,900	20	125	2,975	930	135	2,150	27	135	3,377
Ceylon	355	235	2,370	30	10	3,000	370	250	2,600	30	10	3,260
Panama Canal Zone	130	30	2,770	30	40	3,000	130	30	2,900	30	40	3,130
Uruguay	450	250	1,700	40	40	2,480	550	250	1,800	45	45	2,640
Greece	550	150	1,600	60	130	2,490	550	150	1,700	60	140	2,600
Peru	500	200	1,700	30	300	2,730	500	200	1,550	30	250	2,530
Irish Free State	1,200	550	280	70	250	2,350	1,200	550	350	80	250	2,430
Czechoslovakia	1,200	400	390	200	30	2,220	Included in Germany					
Finland	1,150	550	130	120	120	2,070	1,200	620	140	130	140	2,230
Hungary	600	480	650	110	120	1,960	650	500	700	120	120	2,090
Algeria	950	300	405	80	120	1,855	1,000	300	480	90	120	1,990
Puerto Rico	540	80	1,100	35	45	1,800	550	90	1,150	40	50	1,880
Palestine	380	440	650	30	200	1,700	400	450	690	30	200	1,770
Jamaica	210	55	1,310	10	35	1,620	230	60	1,400	10	40	1,740
Portugal	620	410	360	70	70	1,530	650	440	400	80	80	1,650
French Morocco	830	90	320	40	140	1,420	900	100	340	50	150	1,540
Hongkong	240	60	790	100	10	1,200	260	70	850	100	20	1,300
Turkey	340	320	440	60	20	1,180	360	330	450	60	20	1,220
Kenya and Uganda	375	145	545	25	10	1,100	400	150	600	30	10	1,190
Siam	190	360	340	60	60	1,010	200	370	370	60	60	1,060
Miscellaneous	5,256	3,048	4,627	657	931	14,519	6,301	3,107	4,756	705	847	15,716
Total	765,079	147,828	744,209	56,810	200,081	1,914,007	798,541	153,407	799,426	59,042	213,467	2,023,883

[a] Consumption figures include crude consumed as such, all its products and related fuels such as Benzol, Natural Gasoline, Alcohol used as Motor Fuel. Oil delivered to ships, bunkers is included in consumption of country where deliveries are made.

TABLE 4.—*Consumption of Petroleum and Related Fuels in Miscellaneous Countries*

BARRELS

Country	1938						1939					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
Yugoslavia	290,000	190,000	295,000	72,000	118,000	965,000	300,000	190,000	300,000	72,000	120,000	982,000
Tunis	370,000	190,000	350,000	30,000	7,000	947,000	380,000	190,000	370,000	30,000	8,000	978,000
Indo China	275,000	315,000	114,000	30,000	115,000	849,000	285,000	320,000	118,000	30,000	118,000	871,000
Bulgaria	150,000	300,000	185,000	80,000	70,000	785,000	160,000	300,000	195,000	80,000	70,000	805,000
Sarawak	12,000	33,000	750,000	4,000	15,000	814,000	14,000	34,000	730,000	4,500	14,000	796,500
Syria	280,000	250,000	135,000	27,000	40,000	732,000	280,000	250,000	130,000	27,000	40,000	727,000
Gold Coast	220,000	80,000	170,000	45,000	35,000	550,000	220,000	80,000	175,000	45,000	35,000	555,000
Guatemala	108,000	31,000	365,000	3,000	13,000	520,000	110,000	32,000	370,000	4,000	14,000	530,000
Italian E. Africa	190,000	95,000	53,000	32,000	30,000	400,000	198,000	100,000	65,000	34,000	31,000	428,000
Latvia	155,000	200,000	7,000	25,000	33,000	420,000	155,000	200,000	9,000	25,000	34,000	423,000
Bolivia	110,000	22,000	220,000	24,000	24,000	400,000	114,000	23,000	225,000	25,000	25,000	412,000
Malta	80,000	140,000	145,000	10,000	5,000	380,000	85,000	148,000	155,000	11,000	5,000	404,000
Ecuador	155,000	43,000	53,000	4,000	137,000	392,000	155,000	44,000	54,000	4,000	130,000	387,000
Southern Rhodesia	210,000	20,000	105,000	23,000	1,000	359,000	220,000	21,000	116,000	25,000	2,000	384,000
Estonia	135,000	65,000	80,000	30,000	40,000	350,000	140,000	70,000	85,000	31,000	40,000	366,000
Lithuania	200,000	40,000	65,000	24,000	1,000	330,000	210,000	43,000	68,000	25,000	1,000	347,000
Dominican Republic	93,800	35,000	182,900	11,800	6,500	330,000	95,000	35,000	190,000	12,000	6,800	338,800
Nigeria	190,000	90,000	28,000	17,200	800	326,000	195,000	90,000	30,000	18,000	1,000	334,000
Belgian Congo	180,000	23,000	35,000	12,000	25,000	275,000	200,000	25,000	40,000	13,000	28,000	306,000
Nicaragua	95,000	29,000	85,000	10,000	10,000	229,000	98,000	30,000	88,000	10,000	10,000	236,000
Cyprus	52,600	30,400	117,000	4,700	300	205,000	55,000	31,000	119,000	5,000	500	210,500
Iceland	113,000	28,000	56,000	5,700	300	203,000	115,000	30,000	59,000	5,900	400	210,300
Tanganyika	87,000	44,000	62,000	1,800	200	195,000	90.000	46,000	65,000	2,000	300	203,300
Newfoundland	115,000	22,000	10,500	10,500	2,000	160,000	118,000	23,000	11.000	11,000	2,500	165,500
Haiti	66,000	28,000	43,000	9,000	2,000	148,000	68,000	29,000	44,000	9,000	2,000	152,000
Madagascar	75,000	35,000	25,000	1,000	1,000	137,000	77,000	36,000	29,000	1,000	1,000	144,000
Bermuda	14,500	17,600	125,000	500	400	158,000	17,000	18,000	104,000	600	500	140,100
Mozambique	65,000	24,000	27,000	12,000	1,000	129,000	67,000	25,000	29,000	13,000	1,200	135,200
British Guiana	30,200	13,100	83,000	5,500	200	132,000	31,000	13,400	84,000	5,600	300	134,300
Barbados	56,000	16,000	48,000	4,000	2,000	126,000	60,000	17,000	50,000	4,500	2,500	134,000
Fiji Islands	42,800	8,800	47,700	3,500	200	103,000	44,000	9,000	49,000	3,700	200	105,900
Others	1,040,000	590,000	560,000	85,000	195,000	2,470,000	1,090,000	605,000	600,000	90,000	203,000	2,588,000
Total	5,255,900	3,047,900	4,627,100	657,200	930,900	14,519,000	5,446,000	3,107,400	4,756,000	676,800	947,200	14,933,400

of Italy as long as that country is not assured—while at war—of its needed civil and military oil supply from other sources than Rumania—a condition that virtually would mean the effective control of the Iraq fields and the eastern Mediterranean by the axis powers. The accompanying chart (Fig. 1) shows that foreign military consumption, and possibly additions to foreign stocks, aggregated 175,000,000 bbl. in 1939, or 18,000,000 bbl. more than in the preceding year.

The effect of the four months old European war has been to decrease the civil consumption in the belligerent countries and to increase it in the neighboring neutrals. The tables show that the civil consumption in the United Kingdom, France and Germany has decreased some 7,400,000 bbl., while civil consumption in Italy, Netherlands, Sweden, Norway, Denmark and Belgium has increased in the aggregate close to 4,000,000 barrels.

DISCUSSION

(Lyon F. Terry presiding)

J. D. Gill,* Philadelphia, Pa.—I want to express a feeling of personal indebtedness to the authors for the material helpfulness of their efforts in collecting and assembling innumerable data and in the making of many estimates, out of which they have constructed this comprehensive world picture of petroleum consumption. The present paper, like its predecessors, has been eagerly awaited by students of the industry, who have been saved an enormous amount of what would otherwise be duplicatory effort. The significance of these figures grows out of the fact that the world-wide usage of petroleum products and the irregular distribution of sources of raw material makes any lack of knowledge of supply-demand relationships in any part of the world a serious impediment to an understanding of competitive forces anywhere else in the world. It is hoped that the authors, or others able and willing, may extend the story by showing statistically the flow of crude and products from source to destination.

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* Atlantic Refining Company.

Chapter IV. Production

Introduction

By James Terry Duce,* Member A.I.M.E.

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from the Circular to Authors.

The field is the unit in this tabulation. In cases of fields extending across State boundaries, such as Rodessa, it is suggested that each State author treat the section of the field in his State as a unit, and by a footnote indicate that the field extends into an adjacent State.

Each space in Table 1 may represent one of four possibilities; either it is not applicable to the particular field, or the proper entry is not determinable, or the proper entry may be determinable but is not determinable from data available to the author, or the proper entry is determinable. When spaces are not applicable, leave blank; in spaces where the proper entries are determinable from data available to the author, please insert *y*; in spaces where the proper entries are determinable by the author, make such entries. *y* implies a hope that in some future year a definite figure will be available.

The entry of an 0 is a positive declaration, and an important declaration where it is in order.

Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely *y*. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entry need not be hedged to such extent as when the quantities are definite yet can be ascertained only approximately by the author.

In cases under definite headings but where figures are only approximate, the author may use *x*.

It is thought that the nearest whole numbers are sufficiently accurate for our purposes except as to percentage of sulphur in oil. If an author desires to report any other figures to tenths, he may do so.

The quantity of gas produced should include, where possible, gas sold or otherwise marketed, and gas blown into the air, burned as flares or otherwise wasted. Segregation of these figures would be interesting if the authors can make such segregation. In any event, the figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

Under the columns on "Depth," the average depth to the top of the productive zones and to the bottom of the productive wells, when subtracted, should give the approximate thickness of the productive zone. For fields where this is not true because of unusually high dip or for some other reasons, it is suggested that the authors indicate in their text the approximate average thickness of the productive zone.

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* Geologist, The Texas Company, New York, N. Y.; Chairman for Production, A.I.M.E. Petroleum Division, 1936–1940.

The net thickness of the producing formation should be the thickness of the producing zone, less the estimated amount to cover the portions of the zone that do not yield oil, such as dense shales, etc. It is recognized that for some fields the authors can only make rough guesses; in such cases, they should enter either x or y, whichever is appropriate, and production per acre-foot will have to be treated in a similar manner. Average production per acre-foot can be calculated by those interested from the figures given.

In classifying wells as to producing methods, enter all wells that are not "flowing" in the column headed "Artificial Lift." If desirable, add footnotes to indicate whether the lift is "pumping," "gas lift" or "air lift."

It is recognized that for many fields it would be very difficult to determine accurately the quantity of each gravity of oil produced. However, the approximate weighted average gravity, which will be representative of the total production can be determined sufficiently accurately to constitute significant information.

FOOTNOTES TO COLUMN HEADINGS—TABLE 1

[a] All fields to be listed alphabetically for the district; or alphabetically by counties in alphabetical order.

[b] Areas where both oil and gas are produced, unless gas is marketed outside the field, are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

[c] Wells producing both oil and gas are classified as "Producing Oil." Gas wells are those producing gas, but include those producing wet gas, from which casinghead gasoline may be produced.

[d] State by letters, as indicated, type of operation: PM, pressure maintenance from early life of field; RP, field repressuring in its later life; SR, repressuring operations of secondary recovery type.

[e] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[f] S, sandstone; H, shale; L, limestone; OL, oölitic limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; Gw, granite wash; P, serpentine.

[g] Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[h] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

Oil and Gas Development in South Arkansas in 1939

By Warren B. Weeks,* Member A.I.M.E.

(New York Meeting, February 1940)

Continued development in the deeper fields discovered during 1937 and 1938 was largely responsible for the 16 per cent (2,913,400-bbl.) increase in production, bringing the 1939 output to 21,376,230 bbl., the largest for South Arkansas since 1929.

The older settled fields continued to decline and Rodessa was added to this classification. Magnolia field accounted for much of the increase, with Schuler field showing only a slight increase. There were 248 wells drilled during 1939, five more than during the previous year. Of 198 wells drilled in proven fields, 21 were dry; 46 of the 50 wildcats drilled were dry. The old depth record of 8332 ft. was increased to the present record of 9028.

Trend of Prospecting

Production from the porous "Reynolds" oölite zone of the Smackover limestone continued to be the objective of prospecting. During the year 20 seismograph, 3 gravity meter, 1 magnetometer, 1 soil analysis and 1 electromagnetic crews were reported in the state. The geophysical work was largely concentrated in three southern counties: Columbia, Lafayette and Union. As indicated in Table 2, the same three counties received most of the important drilling tests. At the end of the year only three seismograph crews remained in the areas.

The area for prospecting Smackover limestone was greatly narrowed during the year by the failure of two "fault zone" wells to find satisfactory permeability in the oölite zone, and by the relatively thin sections of porosity found in wells drilled in townships 18 and 19 South.

Geology

Most of the wells listed in Table 2 afforded additional control on structure of the lower beds, but gave little new information on stratigraphy. Of the 248 wells drilled, 3 ended in Tertiary, 34 in Gulf, 1 in Paluxy, 29 in Glen Rose, 15 in Travis Peak, 15 in Cotton Valley, 139 in Smackover, 2 in Eagle Mills and 10 in Carboniferous. The age of the beds between the Travis Peak formation and Carboniferous is still questionable. Most

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Summarized at meeting; manuscript received at the office of the Institute March 18, 1940.

* District Geologist, Phillips Petroleum Co., El Dorado, Arkansas.

TABLE 1.—*Oil and Gas Production in South Arkansas*

			Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939	
										During 1939		End of 1939			Number of Wells	
Line Number	Field, *County*	Year of Discovery	Oil	Gas[b5]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
1	Atlanta, *Columbia*	1938	400[4]	0	109,970	108,000	0	0	6	5	0	0	6	0	6	0
2	Big Creek, *Columbia*	1939	40[4,7]	0	620	620	15*y*	15*y*	1	1	0	0	1	0	1	0
3	Bradley, *Lafayette*	1925	80	0	186,705	0	0	0	6	0	0	0	0	0	0	0
4	Buckner, *Columbia, Lafayette*	1937	1,000[4]	0	1,038,195	675,805	0	0	19	10	0	0	19	0	17	2
5	Camden, *Ouachita*	1934	10	0	37,610	780	0	0	1	0	0	0	1	0	0	1
6	Champagnolle, *Union*	1927	2,040	*x*	14,186,945	573,560	*x*	*x*	237	4	4	10	87	1	0	87
7	Dorcheat, *Columbia*	1939	300[4]	0	37,930	37,930	*y*	*y*	3	3	0	0	3	0	3	0
8	East El Dorado, *Union*[1]	1922	1,420	*x*	9,277,545	129,410[8]	*x*	0	189	2	10	0	56	3	0	56
9	El Dorado, *Union*	1920	8,000	*x*	47,463,410	487,700	*x*	0	1,115	0	6	7	213	0	0	213
10	Garland City, *Miller*[2]	1932	300	0	1,858,360	111,350	0	0	28	0	1	7	15	0	0	15
11	Irma, *Nevada*	1921	900	*x*	6,654,515[6]	212,720	*x*	0	150	0	0	4	73	0	0	73
12	Lewisville, *Lafayette*[3]	1939	300	0	134,120	134,120[9]	0	0	11	11	0	0	11	0	7	4
13	Lisbon, *Union*	1925	2,700	*x*	6,627,425	89,880	*x*	0	356	0	0	1	149	0	0	149
14	Magnolia, *Columbia*	1938	4,000[4]	0	3,726,050	3,595,580	*x*	*x*	82	76	0	0	82	0	82	0
15	Mt. Holly, *Ouachita*	1929	60	0	117,085	0	0	0	6	0	0	0	0	0	0	0
16	Rodessa, *Miller*[3]	1937	2,000	200	5,092,345	1,421,160	24,406	10,008	120	11	23	3	84	6	10	74
17	Schuler, *Union*	1937	4,350	0	13,901,190	6,417,445			168	37	0	0	168	0	154	14
18	Morgan sands	1937	350	0	1,830,620	334,725	0	0	11	0	0	0	11	0	0	11
19	Jones sand	1937	3,300	0	10,730,320[10]	5,192,930	0	0	141	31	0	0	141	0	138	3
20	Reynolds oölite	1937	700	0	1,340,250	889,790	*y*	0	16	6	0	0	16	0	16	0
21	Smackover, *Ouachita, Union*	1922	25,760		378,326,080	6,080,955			3,741	5	79	60	1,699	5	0	1,699
22	Heavy (Norphlet)	1922	16,000	*x*	324,203,000	5,353,065	*x*	*x*	*y*	5	48	50	1,171	5	0	1,171
23	Light (Luann)	1922	9,600	*x*	53,959,940	697,130	*x*	*x*	*y*	0	30	10	525	0	0	525
24	Snow Hill	1936	160	*x*	163,240	30,760	*x*	0	6	0	1	0	3		0	3
25	Stephens, *Columbia Nevada, Ouachita*	1922	3,000	*x*	6,357,850	194,655	*x*	0	306	0	0	0	199	0	0	199
26	Troy, *Nevada*	1936	290	0	1,134,680	412,205	0	0	26	8	0	0	26	0	0	27
27	Urbana, *Union*	1930	500	*x*	4,925,505	386,570	*x*	0	48	0	0	1	38	0	0	38
28	Village, *Columbia*	1938	600	0	375,170	305,785	*y*	*y*	11	7	0	0	11	0	11	0
29	Total		58,050		501,569,305	21,376,230			6,630	180	123	93	2,941	15	291	2,651

[b] Footnotes to column heads and explanation of symbols are given on page 239

[1] Including the new Lawson area and other small producing areas.

[2] Includes the single Glen Rose producer in sec. 24, T. 15 S., R. 26 W.

[3] Information largely furnished by L. D. Bartell, East Texas Refining Co., Dallas, Texas.

[4] Areas of Atlanta, Big Creek and Dorcheat are still undefined. Slight extensions may be expected at Buckner and Magnolia.

[5] Champagnolle, East El Dorado, El Dorado, Irma, Lisbon and Smackover produced large quantities of gas in earlier years, some of which was used commercially. Stephens produced some gas from the Nacatoch, and Urbana from the 2700-ft. sand. The gas at Snow Hill was quickly dissipated. The Jones sand and Reynolds oölite at Schuler have gas reserves, but gas is not being produced commercially at present although 800,000,000 was taken from the Reynolds oölite. Magnolia, Big Creek, Dorcheat and Atlanta have gas reserves that have not yet been used commercially.

[6] Includes 135 bbl. produced at Falcon in 1938.

[7] This is a gas-distillate area.

[8] Including 3705 bbl. from two pumping wells at Lawson (Graves and Meekin sands).

[9] Includes one well producing from the Tokio or Blossom sand at 2347 feet.

[10] Last year's reported Jones sand production of 5,197,775 bbl. should be corrected to 5,203,845 bbl., an addition of 6070 barrels.

geologists of this area agree that they are of Mesozoic age and there is some evidence that they are Jurassic.[1]

NEW FIELDS

Dorcheat.—On Aug. 28, 1939, the Atlantic Refining Company's Pinewoods Lumber Co. No. 1, sec. 16, T. 18 S., R. 22 W. in southwestern

TABLE 1.—(*Continued*)

	Reservoir Pressure, Lb. per Sq. In.[11]		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
									Depth, Avg. Ft.					
Line Number	Initial	Avg. at End of 1939	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	3,844*e*	3,810*e*	44	0.6	Smackover ls.	Jur?	OL	17.6	8,202	8,227	25	A	Smackover ls.	8,332
2	*y*	*y*	69	*y*	Smackover ls.	Jur?	OL	13.4	7,959	7,995	36	A	Smackover ls.	7,999
3	*y*	*x*	27	*y*	Buckrange ss.	CreU	S	Por	2,785	2,790	5	A	Paluxy	3,555
4	3,200*e*	2,850*e*	32	0.3	Smackover ls.	Jur?	OL	10 to 20	7,200	7,260	60	A	Smackover ls.	7,444
5	*y*	*y*	17	*y*	Nacatoch ss.	Cre	S	Por	1,356	1,369	13		Travis Peak	2,500
6	*y*	*y*	32	1.1	Tokio Travis Peak	CreU CreL	S	Por	2,780 3,340	2,800 3,350	15	NL	Eagle Mills salt	6,911
7	4,165*e*	4,165*e*	44	0.4	Smackover ls.	Jur?	OL	15.0	8,815	8,875	60	A	Smackover ls.	9,028
8	*y*	*y*	20	1.8	Nacatoch ss.	CreU	S	Por	2,170	2,180	10	TL	Cotton Valley	6,003
9	*y*	*y*	32	1.0	Nacatoch ss.	CreU	S	Por	2,100 2,550 2,950	2,177	20	ANL	Travis Peak	3,396
10	*y*	*y*	31	1.2	Paluxy and Glen Rose	CreL	S	Por	2,925 4,200	2,935 4,215	10	ML	Smackover ls.	7,310
11	*y*	*y*	14	2.7	Nacatoch ss.	CreU	S	Por	1,150	1,179	27	AF	Travis Peak	3,735
12	1,450	1,050	42	0.6	Lower Glen Rose	CreL	OL, S	17.0	3,400	3,500	20	TF	Smackover ls.	7,420
13	*y*	*y*	35	1.0	Nacatoch ss.	CreU	S	Por	2,100	2,120	20	ML	Travis Peak	3,509
14	3,555*e*	3,380*e*	38	0.9	Smackover ls.	Jur?	OL	16.1	7,350	7,600	100	A	Smackover ls.	7,824
15	*y*	*x*	30	*y*	Travis Peak	CreL	S	Por	2,800	2,813	7	ML(?)	Travis Peak	3,378
16	2,500*y*	300*y*	44	*y*	Lower Glen Rose	CreL	OL, LS	5.0 to 30.0	6,050	6,100	25	AF	Lower Glen Rose	6,514
17									5,600	7,635	88	A	Smackover ls.	8,328
18	2,000*y*	*x*	40	0.5	Cotton Valley	Jur?	S	15.0	5,600	5,885	20	AL		
19	3,520*e*	2,339*e*	30	1.5	Cotton Valley	Jur?	S	17.6	7,530	7,610	42	A		
20	3,545*e*	3,448*e*	38	0.9	Smackover ls.	Jur?	OL	14.3	7,600	7,635	26	A		
21	*x*	*x*							2,000	4,960	100	Af	Igneous	7,973
22	*y*	*y*	20	2.2	Nacotoch Graves Tokio	CreU	S	Por	2,000 2,450 2,600	2,025 2,475 2,610	40	Af	Eagle Mills salt	7,255
23	*y*	*y*	22	1.8	Nacatoch, Meekin	CreU	S	Por	2,000 2,275	2,025 2,300	30	ALf	Igneous	7,973
24	*x*	*x*	35	1.0 1.3	Smackover ls.	Jur?	OL	25.0	4,800	4,960	30	Af	Eagle Mills salt	5,708
25	*y*	*y*	31	1.6 2.9	Nacatoch ss. Buckrange ss.	CreU	S	Por	1,500 2,100	1,510 2,110	15 7	NLf	Smackover ls.	6,053
26	*y*	*y*	20	*y*	Nacatoch ss. Blossom ss.	CreU	S	Por	1,243 2,160	1,250 2,167	10	F	Eagle Mills salt	6,143
27	*y*	*y*	18	2.1	Nacatoch ss. Travis Peak	CreU CreL	S	Por	2,270 3,550	2,280 3,560	10	A	Cotton Valley	4,501
28	3,350*e*	3,323*e*	45 56	0.3	Smackover ls.	Jur?	OL	14.0	7,390	7,450	50	A	Smackover ls.	7,603
29														

[11] *e* indicates bottom-hole pressure.

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[1] R. W. Imlay: Manuscript in preparation describing stratigraphic information obtained from the recent drilling in South Arkansas. This bulletin, to be published by the Arkansas Geological Survey, will discuss evidence as to the age of the deeper beds as well as give a historical interpretation.

Columbia County, was completed for 528 bbl. of 44° gravity oil per day on $\frac{9}{32}$ in. choke. Production comes from Reynolds oölite zone from 8815 to 8871 ft. in the Smackover limestone. This deepest production in South Arkansas was discovered as a result of seismograph work in an area previously thought to be "structurally high" from subsurface correlation of Gulf beds.

Three wells had been completed by the end of the year and had produced 37,930 bbl. of oil and three wells were drilling. A spacing program of one well to 40 acres is being followed. Development will be slow because the structure is largely a gas-distillate reserve. The field was named from the local community.

Big Creek.—Standard Oil Company of Louisiana completed Petty Stave Company's No. 1 on Dec. 23, 1939, for the eighth Reynolds oölite zone field of this area. This well is in sec. 4, T. 17 S., R. 21 W., a few miles northwest of the town of Magnolia, Columbia County. From a depth of 7955 ft. the well produced 168 bbl. of 69° gravity colorless oil with 4,108,000 cu. ft. of gas. This gas-distillate field, which was discovered by seismograph work, will probably cover only a small area. The field received its name from a near-by stream.

Lewisville.—East Texas Refining Co. completed Patton No. 1 in sec. 24, T. 16 S., R. 24 W., on April 25, 1939, as the second field producing from the Rodessa member of the Glen Rose in South Arkansas. The well flowed 168 bbl. per day of 42° gravity oil on open choke. Production comes from 3410 ft. in an oölitic and sandy limestone zone immediately below the Glen Rose anhydrite. One well produces from the Blossom

TABLE 2.—*Summary of Drilling Operations in South Arkansas*

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	Bradley	14	17 S	10 W	5,310	Cockfield	Smackover ls.
2	Calhoun	17	14 S	13 W	5,007	Cockfield	Eagle Mills anhydride
3	Columbia	16	18 S	22 W	9,002	Sparta	Smackover ls.
4	Columbia	4	17 S	21 W	7,999	Claiborne	Smackover ls.
5	Columbia	4	17 S	21 W	8,510	Claiborne	Smackover ls.
6	Columbia	36	16 S	20 W	7,778	Sparta	Smackover ls.
7	Columbia	31	17 S	18 W	7,858	Cockfield	Smackover ls.
8	Columbia	15	18 S	22 W	9,028	Sparta	Smackover ls.
9	Columbia	9	16 S	22 W	7,272	Claiborne	Smackover ls.
10	Lafayette	24	16 S	24 W	3,606	Wilcox	Lower Glen Rose
11	Lafayette	13	16 S	24 W	7,420	Wilcox	Smackover ls.
12	Lafayette	15	19 S	26 W	6,801	Claiborne	Travis Peak
13	Ouachita	23	15 S	19 W	6,053	Claiborne	Smackover ls.
14	Ouachita	29	15 S	17 W	6,092	Cook Mountain	Smackover ls.
15	Ouachita	27	15 S	18 W	1,618	Cook Mountain	Nacatoch sand
16	Union	13	18 S	12 W	6,290	Cockfield	Smackover ls.
17	Union	22	19 S	14 W	7,939	Cockfield	Smackover ls.
18	Union	6	18 S	13 W	4,601	Cockfield	Cotton Valley

sand at 2305 ft. in basal Gulf. The eleven wells completed to the end of the year had produced 134,120 bbl. of oil. By that time four wells were pumping. The accumulation is due to structural closure against a fault and the field was discovered by subsurface correlation. Porosity conditions are poor and the area and recovery are expected to be small. Spacing of one well to 20 acres is being followed. The field was named from the town of Lewisville, several miles to the west, and is the third producing area for Lafayette County.

West McDonald.—On Nov. 8, 1939, Sherry O'Brien completed Cook Estate No. 1, sec. 27, T. 15 S., R. 18 W., southern Ouachita County, for an estimated 20,000,000 cu. ft. of gas on ½-in. choke from a depth of 1588 ft. in the Nacatoch sand. The well has been shut in since completion. The structure consists of closure against a fault and covers only a small area. Discovery was due to subsurface well correlation. This well is several miles west of the abandoned McDonald (Mt. Holly) field.

EXTENSIONS AND DEVELOPMENT

Lawson.—During August of 1939, Lion Oil Refining Co. deepened an abandoned small Nacatoch-sand gas well in sec. 6, T. 18 S., R. 13 W., and

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Amerada Petr. Corp.						Dry hole
2	J. R. Lockhart et al.						Dry hole
3	Atlantic Ref. Co.	528	2,000,000	$^{18}/_{64}$	1,150	750	Discovery well, Dorcheat field
4	Standard Oil Co. of La.	168	4,000,000	$^{14}/_{64}$	2,375	2,325	Discovery well, Big Creek field
5	Phillips Petr. Co.						Dry hole
6	Standard Oil Co. of La.						Dry hole
7	Twin City Syndicate						Dry hole
8	Lion Oil Ref. Co.	300	1,900,000	$^{13}/_{64}$	3,150	2,900	Deepest well in state
9	Standard Oil Co. of La.	192	71,000	$^{25}/_{64}$	50	60	East extension, Buckner field
10	East Texas Ref. Co.	168		open	100	400	Discovery well, Lewisville field
11	Shell Oil Co. et al.						Dry hole: Smackover limestone not permeable
12	Wadley & Irwin						Dry hole
13	Deep Rock Oil Corp.						Dry hole: Smackover limestone not permeable
14	Lion Oil Ref. Co.						Dry hole
15	Sherry O'Brien	0	20,000,000	$^{32}/_{64}$			Discovery well, West McDonald
16	Joe Modisett						Dry hole
17	Oliphant Oil Corp.						Dry hole
18	Lion Oil Ref. Co.	65				pump	Discovery well, Graves sand, Lawson area

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	27	17
Number of oil wells completed during 1939	176	2
Number of gas wells completed during 1939	1	2
Number of dry holes completed during 1939	21	46

completed it in the Graves sand at 2674 ft., pumping 65 bbl. of 23° gravity oil per day with a large quantity of water. A subsequent well pumps 25 bbl. of 17° gravity oil and a large quantity of water per day from the Meekin sand at 2583 ft. Two other tests were dry in these sands and the area will see no further development.

Magnolia.—The Magnolia field, Columbia County, led in drilling development for this area with the completion of 76 oil wells from the Reynolds oölite zone. Three dry holes were drilled. With approximately 4000 acres proven, 82 wells completed and 10 drilling operations, the field had developed into a major producing area, most estimates of recovery running well over 100,000,000 bbl. Owing to "water-drive"[2] the reservoir pressure has declined very little from the original. This field should be completely developed during 1940.

Schuler.—In the Schuler field, Union County, 37 oil wells and 2 dry holes were completed. Five of the wells were completed from the Reynolds oölite zone, the remainder from the Jones sand. Both reservoirs were practically fully developed by the end of the year. The combined acreage for the three reservoirs—the Morgan sand zone, the Jones sand zone and the Reynolds oölite zone—will stand at approximately 4350 acres. Reservoir pressure in the Jones sand dropped approximately 1200 lb. during the year, with no evidence of water encroachment.[3] The reservoir pressure of the Reynolds oölite zone dropped only 100 lb., being maintained by the natural water drive of that zone.

Other Fields.—Although 11 oil wells and 1 dry hole were drilled in *Rodessa* field, Miller County, during 1939, the productive area was not greatly extended. Reservoir pressure had dropped to 300 lb. and only 10 of 84 wells were flowing naturally. Little or no further development is expected. The Standard Oil Company of Louisiana's Johnson No. 1, in sec. 9, T. 16 S., R. 22 W., was an east extension for *Buckner* field, Columbia County. Nine other wells were completed and two wells were near completion at the end of the year. It is expected that this 1000-acre Reynolds oölite zone field will see little more development. *Troy*, Nevada County, had eight pumping wells completed, one from the Nacatoch sand, the remainder from the Blossom sand. Two dry holes were drilled. One well was drilling at the close of the year. *Village*, Columbia County, had seven oil wells and one dry hole. The field is defined and developed at 600 acres. *Atlanta*, Columbia County, had five oil wells added, including an east one-mile extension, which should cause from 10 to 15 additional wells.

There was little development in the older settled pools. *Champagnolle*, Union County, had four oil wells and two dry holes. In the same county,

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[2] A. M. Crowell: Development and Early Exploitation of a Water-driven Oil Pool under Proration. *Petr. Engr.* (Nov. 1939) 21–26.

[3] A. M. Crowell: Data on Gas-driven Pool Discloses Characteristics Differing from Water-driven Reservoirs. *Petr. Engr.* (Oct. 1 939) 25–30.

Smackover had four small oil wells and a gas well; *Urbana* and *El Dorado* had one dry hole each.

Falcon, reported as a new field in sec. 9, T. 15 S., R. 22 W., Nevada County, last year, was abandoned after the two wells proved unprofitable and a third well was dry.

REGULATION OF PRODUCTION AND DEVELOPMENT

The Arkansas Oil and Gas Commission was set up by legislative act early in 1939 and supplanted the old Arkansas Board of Conservation. The statute gave the new body wide powers of conservation control, and this Commission has functioned ably in collecting data from various fields and in enforcing production and development rules. The following recent flush fields have been regulated:

Field	Well Spacing, Acres	Producing Formation	Field	Well Spacing, Acres	Producing Formation
Atlanta	40	Reynolds oölite zone	Schuler	40	Reynolds oölite zone
Buckner	40	Reynolds oölite zone	Schuler	20	Jones sand
			Village	40	Reynolds oölite zone
Magnolia	40	Reynolds oölite zone			

Because of the small production and early dissipation of pressure, control was unnecessary for Snow Hill, Rodessa and Lewisville. Big Creek and Dorcheat are following the 40-acre spacing pattern and production will be prorated as further wells are drilled.

Production is allocated to wells within the controlled fields by formulas based on the product of two factors, acreage and bottom-hole pressure, with the exception of the Village field, where a more complicated formula limits wells having high gas-oil ratio to a certain maximum reservoir voidage. Some operators in the Schuler field have petitioned the Commission to adopt a formula for the Jones sand reservoir, taking into account the original oil in place under various leases. It seems probable that this question may be carried into court.

ACKNOWLEDGMENTS

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Developments in California Oil Industry during 1939

By V. H. Wilhelm,* Member A.I.M.E.

(New York Meeting, February 1940)

Drilling activity in California during 1939 decreased approximately 15 per cent from that of the previous year. New reserve discoveries were the lowest in many years, but extensions, development of deeper sands, and reappraisals, indicated enough new potential to more than equal 1939 withdrawals of about 223,644,000 barrels.

On June 1 a new uniform method of allocation was adopted, which had the immediate effect of reducing production, so that approximately 6,000,000 bbl. of crude were withdrawn from storage during the year. Market demand averaged 628,845 bbl. per day as compared with a daily production of 612,945 barrels.

The rate of drilling was slow during the first five months because of the unfavorable storage situation. Subsequent to the adoption of the new uniform method of allocation on June 1, drilling was speeded up and continued at a rapid rate throughout the remainder of the year.

As a result of prospecting, four new fields were discovered and seven fields were measurably extended. All of the new discoveries were made in the San Joaquin Valley.

Statistics of production and development are given in Fig. 1 and Tables 1 to 3.

New Discoveries

Coalinga-Northeast.—The Amerada Petroleum Corporation discovered a second Eocene shore-line field north of the Coalinga Nose when it brought in well S.P.L. 7-17 in sec. 17-19-16, flowing 4230 bbl. of 32.4° gravity oil and 14,200,000 cu. ft. of gas at a depth of 8237 ft., from the "Gatchell" sand of Eocene age. This field, 2 miles north of the Coalinga Nose field, is considered to be a separate structure because it has a gas cap and a lower water table. The structure is a broad, gentle anticlinal nose probably separated from the southerly Coalinga Nose field by a shallow syncline. Production is sealed updip by the pinching out of oil sands. The average sand thickness is approximately 200 ft., the top 75 ft. containing mainly gas. The sand has an average permeability of 1000 millidarcys and an average porosity of 25 per cent. The productive area of the field is estimated to be between 1200 and 1500 acres.

Summarized at meeting; manuscript received at the office of the Institute March 22, 1940.

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Mountain View Field (South).—The discovery of the South Mountain View field was the result of the combined operations of the Standard Oil Co., Superior Oil Co. and The Texas Company. It is 2 miles south of the main Mountain View field along the Mountain View fault. The discovery well, Standard Oil Company's Jewett No. 1, was brought in flowing 2875 bbl. of 37.1° gravity oil and 900,000 cu. ft. of gas from the Chanac formation of Pliocene age. The structure is monoclinal, sealed by the main Mountain View fault on the east and cross faulting on the north. The estimated productive area of the field is 120 acres, having an average net sand thickness of 60 ft. This sand has a permeability of 500 millidarcys and a porosity of 24 per cent.

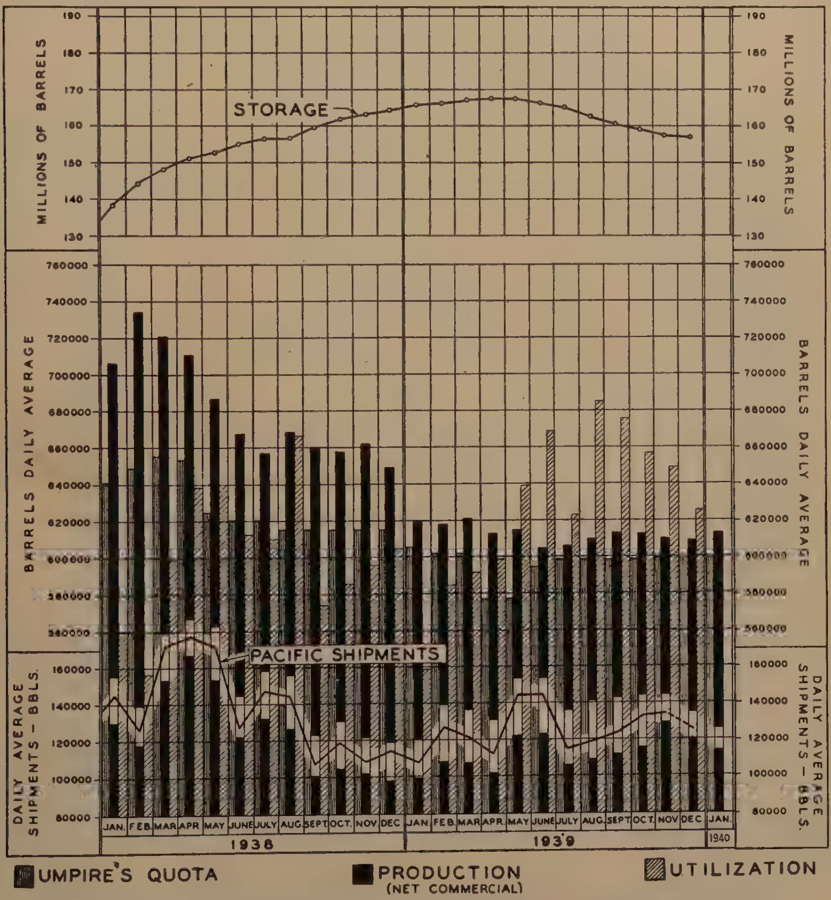

FIG. 1.—PRODUCTION, SHIPMENTS AND STORAGE OF OIL, CALIFORNIA.

Paloma Field.—The Paloma field, 14 miles southwest of Bakersfield, was discovered by the Western Gulf Oil Co., in partnership with The Texas Company. Geophysical exploration was responsible for outlining

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1939	During 1939
	SAN JOAQUIN VALLEY				
1	Arvin, *Kern*	1937	120	45,634	21,771
2	Belridge, North, *Kern*	1912	1,837	36,384,298	4,345,343
3	Belridge, South, *Kern*	1911	2,300	21,578,865	406,762
4	Canal, *Kern*	1937	920	2,733,246	1,854,188
5	Coalinga, East, *Fresno*	1896	5,300	216,788,992	1,379,727
6	Coalinga, West, *Fresno*	1901	10,830	142,658,281	1,933,471
7	Coalinga, Eocene, *Fresno*	1938	2,800	2,427,237	2,181,170
8	Coalinga, Northeast, *Fresno*	1939	1,200	181,825	181,825
9	Coles Levee, *Kern*	1938	2,790	536,624	524,966
10	Edison, *Kern*	1931	1,240	6,467,874	828,020
11	Elk Hills, *Kern*	1919	7,870	149,821,221	3,820,922
12	Fruitvale, *Kern*	1928	2,050	20,261,770	2,342,622
13	Greeley, *Kern*	1936	1,900	2,505,987	811,203
14	Kern Front, *Kern*	1925	3,960	43,298,542	2,475,210
15	Kern River, *Kern*	1899	6,100	274,480,285	1,137,371
16	Kettleman, Middle, *Kern*	1932	200	533,903	8,811
17	Kettleman, North, *Fresno, Kern*	1928	15,887	221,509,226	19,546,684
18	Lost Hills, *Kern*	1910	1,550	48,672,888	1,208,549
19	McKittrick, *Kern*	1898	1,565	89,668,532	1,309,477
20	Midway-Maricopa, *Kern*	1894	54,177	876,622,555	18,930,074
21	Mountain View, *Kern*	1930	2,050	35,243,073	3,379,522
22	Mt. Poso Dist., *Kern*	1926	3,490	46,779,395	4,198,580
23	Paloma, *Kern*	1939	400	23,207	23,207
24	Premier, *Kern*	1929	690	2,980,126	543,053
25	Richfield Western, *Kern* (Tupman)	1938	750	With Coles Levee	
26	Rio Bravo, *Kern*	1937	2,000	4,943,057	2,871,094
27	Round Mountain, *Kern*	1927	1,669	16,878,292	2,676,225
28	Strand, *Kern*	1939	380	137,939	137,939
29	Ten Sections, *Kern*	1936	2,100	6,893,175	3,264.497
30	Wasco, *Kern*	1938	380	527,302	402,238
31	Wheeler Ridge, *Kern*	1922	260	3,703,594	124.729
32	Others			8,567,154	831,489
33	San Joaquin Valley total			2,283,854,099	83,700,739
	COASTAL DISTRICT				
34	Capitan, *Sta. Barbara*	1929	296	4,255,474	875,772
35	Elwood, *Sta. Barbara*	1928	400	65,969,726	1,545,508
36	Santa Barbara, *Sta. Barbara*	1929	132	3,195,732	100,557
37	Summerland, *Sta. Barbara*	1892	180	3,145,470	9,776
	SANTA MARIA DISTRICT			150,805,624	(6,372,444)
38	Casmalia, *Sta. Barbara*	1904	1,010	[2]	84,491
39	Cat Canyon, *Sta. Barbara*	1908	1,062	[2]	183,490
40	Gato Ridge, *Sta. Barbara*	1931	300	[2]	907,723
41	Lompoc, *Sta. Barbara*	1903	2,215	[2]	107,274
42	Orcutt, *Sta. Barbara*	1901	4,220	[2]	851,772
43	Santa Maria Valley, *Sta. Barbara*	1934	5,230	[2]	4,237,694
	VENTURA DISTRICT				
44	Padre Canyon, *Ventura*	1936	165	1,029,386	254,756
45	Rincon, *Ventura*	1927	380	10,963,892	1,235,583
46	San Miguelito, *Ventura*	1930	180	3,926,444	696,540
47	Ventura Avenue, *Ventura*	1916	1,840	213,239,323	12,907,844
	VENTURA NEWHALL DISTRICT			61,279,066	(1,772,494)
48	Aliso Canyon, *Los Angeles*	1938	100	228,595	23,416
49	Bardsdale, *Ventura*	1894	287	[3]	52,155
50	Oxnard, *Ventura*	1937	490	[3]	74,319
51	Elsmere Canyon, *Los Angeles*	1889	230	[3]	S.I.
52	Ex-Mission, *Ventura*	1875	130	[3]	12,178
53	Hopper Canyon, *Ventura*	1887	150	[3]	43,000
54	Modelo, *Ventura*	1898	60	[3]	4,350

[b] Footnotes to column heads and explanation of symbols are given on p. 239.

[2] With Santa Maria.

[3] With Ventura Newhall.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-Production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.	Gasoline per M Cu. Ft.	Repressuring Operation[d]	Character of Oil			
				During 1939		End of 1939		Number of Wells					Gravity A.P.I. at 60°F., Weighted Average			
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down, Idle	Producing Oil	Flowing	Artificial Lift[1]	Initial			Max.	Min.		Sulphur Per Cent
1			2				2		2						30	
2	212,805	44,366	104	13		33	71	61	10		0.56	RP	41	30	36	
3			256			138	118	1	117				26	14	24	
4	With Strand		31	16			31	30	1	3,600			38	36	37.5	
5	1,397	261	584			430	154		584				24	19	2.1	
6			725	9	12	76	649		725				23	12	15.8	0.45
7			50	50		2	48	50		3,200					33	
8			9				9	9							28	
9			14	8			14	14							44	
10	With Mt. View		95	5	4	6	89	0	89				26	15	18.5	
11	86,215	1,608	249	5	2	56	193	0	193		2.31		25	15	22.1	0.57
12			180	8	9	14	166	14	152				24	14	19.8	0.60
13	12,833	3,107	27	11	1	2	25	15	10		0.58		60	32	38.5	0.28
14			446	1		54	392		392				15	12	14.4	
15			2,172	32	3	931	1,241		1,241				14	12	13.3	
16	14,065	518	3			2		2			1.08		58	48	55.1	
17	1,309,272	99,724	276	38	4	29	247	104	143	3,150 4,500	1.48		37	34	36.5	0.30
18			403	1		111	292		292				36	13	18.0	
19			313	4	2	100	213		213				18	13	14.2	
20	351,167	13,358	3,582	18	29	947	2,635	2	3,580		1.96		28	12	17.5	0.65
21	44,282	3,264	189	16	9	2	187	11	178		1.15		26	21	26.0	0.44
22			330	12		85	245		245				16	14	15.2	
23			1	1			1	1		4,294					47.4	
24			82	9		7	75		75				15	12	14.3	
25			5	3			5	4	1				48	38	44	
26	3,307	2,406	38	13			38	38			0.42		40	37	38.5	
27			232	12	1	30	202		232				17	13	16.5	
28	121	121	6	6			6	6		3,600					34	0.37
29	12,127	4,160	46	11		5	41	40	5		0.55		38		35.4	
30			7	4			7	6	1				38		37.7	
31			34	1			34		34				23	23	23.5	
32		262	9				9		9							
33		173,155	10,500	307	76	3,060	7,439	409	8,524							
34	2,526	721	55			10	45	2	53		1.37		43	18	28	
35	58,906	2,369	81			11	71	2	79		1.43		41	22	33.7	
36			28	3	19	1	27		28				19	14	17	
37			9			1	8		9				19	17	18	0.84
38			64			58	6		64				20	8	10.3	2.1
39			65			58	7		65				15	10	13.5	1.5
40			17	3		14	3		17				14	13	13.9	
41			35			28	7		35				21	20	20.5	4.4
42			226	1	3	99	127		26				26	18	22.6	1.6
43		1,830	149	12		87	62	45	2104				17	13	15.9	
44	12,494	1,742	10	1			10	1	9				31	28	29.1	
45			62	6	2	2	60	9	51				30	27	30	
46	5,508	725	13	3	1	1	12	11	2				34	29	30	
47	744,921	37,127	380	35		106	274	120	260				50	12	30	
48			4	3	3		4		4						24	
49			34			5	29		34				33	22	32.1	1.7
50			3	3		1	2		3				8	8	8	
51			9			9	0		9				23	14	16	
52			24			1	23		24				28	24	24.5	0.70
53			11	1			11		11				31	18	29	
54			15			5	10		15				26	26	26.1	

[1] Pump and gas lift.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Chanac	Pli	S		7,300	7,288		MF	Granite	7,928
2	Etchegoin, Temblor, Vaqueros	Pli-Mio	S	15.1	4,917	7,152	500[4]	A	Eoc	9,682
3	Etchegoin, Temblor	Pli-Mio	S		800	874	y	A	Mio	11,377
4	Stevens	Mio	S	20	8,250	8,297	190	A	Mio	8,350
5	Etchegoin-Temblor	Pli-Mio	S	25	1,860	2,076	70	AUP	Cre	9,418
6	Etchegoin, Sta. Margarita	Pli-Mio	S		900	1,580	80	MUP	Cre	4,833
7	Avenal	Eoc	S	22	6,400	7,440	360	MU	Eoc	8,416
8	Avenal	Eoc	S	25	8,100	8,208	150	MU	Cre	9,614
9	Stevens	Mio	S	24		9,621	100	MU	Mio	9,977
10	Kern River, Temblor	Pli-Mio	S		2,000	2,239	125	MU	Granite	
11	Etchegoin	Pli	S		2,600	3,115	y	A	Mio	8,404
12	Etchegoin, Chanac	Pli	S		3,000	3,685	88	MU	Schist	8,531
13	Stevens, Vedder	Pli	S	22	7,720 11,430	7,800 11,500	45 95	AM	Mio L	12,504
14	Etchegoin	Pli	S		1,700	2,175	60	MF	Mio	2,650
15	Kern River	Pli	S		400	837	300	MU	Olig	4,852
16	Temblor	Mio	S		7,563	7,825	y	A	Mio	9,138
17	Temblor Avenal	Mio-Eoc	S	16	6,300 10,200	8,236 10,851	300 45	A	Eoc	11,746
18	Etchegoin	Pli	S		1,170	1,204	80	A	Mio	7,858
19	Etchegoin	Pli	S		800	1,107	90	MU	Mio	6,664
20	Etchegoin, Maricopa	Pli-Mio	S		1,950	2,095	100	MU	Mio	9,735
21	Chanac, Sta. Margarita	Pli-Mio	S		5,140	5,589	100	MF	Mio	8,419
22	Vedder	Mio	S	35	1,600	1,745	90	MF	Granite	3,130
23	Stevens	Mio	S	20	10,030	10,175	122	A	Mio	10,475
24	Etchegoin	Pli	S		2,440	2,540	y	MF	Olig	6,073
25	Stevens	Mio	S			8,702	600	MU	Mio	10,120
26	Rio Bravo, Vedder	Mio	S		11,249	11,495	220	A	Eoc	14,108
27	Etchegoin	Pli	S		1,600	1,861	66	MF	Olig	6,070
28	Stevens	Pli	S		8,250	8,325	50	D	Mio	8,330
29	Stevens	Pli	S	22	7,850	8,216	200	A	Mio	8,984
30	Vedder	Pli	S	18	13,100	13,143	32	A	Eoc	15,004
31	Etchegoin, Sta. Margarita	Pli-Mio	S		2,000	2,717	y	A	Olig	11,004
32						2,100				
33										
34	Vaqueros, Sespe	Mio, Olig	S	25	1,150	1,400 2,734	305	AF	Sespe	4,071
35	Monterey, Vaqueros, Sespe	Mio, Olig	S		2,800	3,128 3,906	320	AF	Eoc	7,157
36	Vaqueros	Mio	S		1,960	2,003	45	MF	Sespe	4,730
37	Pliocene, Vaqueros	Pli-Mio	S		400	876		A AF	Sespe	5,041
38	Monterey	Mio	H		1,200	1,679	Fis	A	Mio	3,900
39	Monterey	Mio	H		2,000	3,000	Fis	A	Cre	7,199
40	Monterey	Mio	H		1,800	3,255	Fis	AF	Vaq, Mio	6,510
41	Monterey	Mio	H		2,200	2,711	Fis	A	Mio	4,310
42	Monterey	Mio	S-H		1,100	3,175	Fis	A	Sespe-Olig	5,815
43	Monterey	Mio	S-H		4,000	4,488	Fis	M	Franciscan	8,133
44	Repetto	Pli	S		4,800	5,872	350	AF	Mio	6,566
45	Repetto	Pli	S		2,500	3,842		A	Pli	7,291
46	Repetto	Pli	S		5,500	7,042	700	AF	Pli	10,030
47	Repetto	Pli	S		3,450	6,629[5]	3,000	A	Pli	11,070
48	Repetto	Pli	S		4,795	5,720	y	MF	Mio	7,200
49	Sespe, Tejon	Olig, Eoc	S		500	888	y	A	Eoc	6,804
50	Modelo	Mio	S			2,905	y	MU	Mio	4,285
51	Repetto	Pli	S		240	800	y	MU	Jurassic schist	2,117
52	Repetto	Pli	S		500	1,585	y	MF		
53	Modelo	Mio	S		1,500	1,828	y	A		2,200
54	Modelo	Mio	S		180	2,050	y			1,488

[4] 380 to 290 ft.
[5] Varies: 624; 7188, 9240.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1939	During 1939
55	Newhall-Potrero, *Los Angeles*	1937	200	671,754	393,303
56	Pico Canyon and Newhall, *Los Angeles*	1875	140	[3]	53,267
57	Sespe, *Ventura*	1887	289	[3]	104,976
58	Shiells Canyon, *Ventura*	1911	503	[3]	467,170
59	Simi, *Ventura*	1912	635	[3]	35,125
60	Sisar-Silverthread, *Ventura*	1885	330	[3]	44,930
61	South Mountain, *Ventura*	1916	785	[3]	552,794
62	Sulphur Mountain, *Ventura*	1927	40	[3]	3,211
63	Tapo-Eureka, *Ventura*	1882	220	[3]	10,468
64	Temescal, *Ventura*	1924	120	[3]	225,237
65	Timber Canyon, *Ventura*	1885	110	[3]	10,606
66	Fresno-Lion Mt., *Ventura*	1917	50	[3]	16,730
67	Torrey Canyon, *Ventura*	1896	140	[3]	50,097
68	Wiley-Towsley Canyon, *Ventura*	1887	28	[3]	5,473
	OTHER COASTAL COUNTIES				
69	Edna, *San Luis Obispo*	1929		729,578	15,681
70	Pismo, *San Luis Obispo*	1928	200	83,113	14,370
71	Half Moon Bay, *San Mateo*	1886	80	39,492	3,275
72	Sargent, *Santa Clara*	1886	60	299,027	8,735
73	Coastal District total			519,913,122	26,230,710
	LOS ANGELES BASIN				
74	Alamitos, *Los Angeles*	1927	110	23,289,026	574,129
75	Brea Olinda, *Orange*	1889	1,910	163,816,830	2,042,405
76	Coyote-East, *Orange*	1911	1,314	79,737,091	953,701
77	Coyote-West, *Orange*	1909	984	80,842,989	3,069,555
78	Dominguez, *Los Angeles*	1923	1,054	114,116,130	7,126,928
79	El Segundo, *Los Angeles*	1935	930	8,818,008	1,156,454
80	Huntington Beach, *Orange*	1920	2,240	280,823,928	9,947,211
81	Inglewood, *Los Angeles*	1924	885	116,439,027	4,598,420
82	Lawndale, *Los Angeles*	1928	72	532,835	15,744
83	Long Beach, *Los Angeles*	1921	1,600	633,346,794	16,794,374
84	Los Angeles District, *Los Angeles*	1896	1,650	65,664,746	182,863
85	Montebello, *Los Angeles*	1917	1,743	115,208,908	7,449,902
86	Playa del Rey, *Los Angeles*	1929	599	44,738,280	1,741,874
87	Potrero, *Los Angeles*	1928	120	2,886,903	400,517
88	Richfield, *Orange*	1919	1,300	88,878,423	2,930,110
89	Rosecrans-Athens, *Los Angeles*	1924	762	40,568,760	4,472,279
90	Santa Fe Spring, *Los Angeles*	1919	1,630	457,640,378	10,055,317
91	Seal Beach, *Los Angeles*	1926	260	61,577,900	2,070,248
92	Torrance, *Los Angeles*	1921	6,905	97,148,734	6,343,344
93	Whittier, *Los Angeles*	1898	495	18,059,801	358,096
94	Wilmington, *Los Angeles*	1936	4,400	79,241,270	31,063,151
95	Others, *Los Angeles*			3,525,335	401,007
96	L. A. Basin total			2,576,902,096	113,747,629
97	State total		192,715	5,380,669,317	223,679,078
	GAS FIELDS				
	NORTHERN GROUP		Gas[b]		B.t.u.
98	Eureka, *Humboldt*	1937	200		940
99	McDonald Island, *San Joaquin*	1936	1,500		965
100	Potrero Hills, *Solano*	1938	100		991
101	RioVista, *Solano and Sacramento*	1936	9,000		1,040
102	Sutter Buttes, *Sutter*	1933	120		1,016
103	Tracy, *San Joaquin*	1935	600		935
104	Willows, *Glenn*	1938	100		990
105	Fair Field Knolls, *Yolo*	1939	150		
	SAN JOAQUIN VALLEY				
106	Buena Vista Lake, *Kern*	1934	1,050		1,000
107	Buttonwillow, *Kern*	1926	1,700		985
108	Chowchilla, *Madera*	1935	300		930
109	Trico (Delano), *Kern*	1935	1,650		980
110	Semitropic, *Kern*	1932	3,750		980
	COASTAL				
111	Goleta, *Sta. Barbara*	1929	250		1,035

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-Production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.			Character of Oil			
				During 1939		End of 1939		Number of Wells								
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down, Idle	Producing Oil[c]	Flowing	Artificial Lift[f]	Initial	Gasoline per M Cu. Ft.	Repressuring Operation[e]	Gravity A.P.I. at 60°F., Weighted Average			Sulphur Per Cent
55			7				7	7	0				35	33	33.3	
56			58		2	8	50		58				38	35	37.3	0.28
57			32	4		16	16		32				36	28	35.1	
58	With So. Mt.		129	6		19	110	12	117			SR	33	33	33.3	
59			57			4	53		57				31	16	28.1	
60			77			7	70		77				24	15	18.5	
61	57,488	3,899	94	1		7	87		94			SR	27	20	23.9	
62			2			1	1		2				16	15	15.5	
63			21				21		21				23	21	22.4	
64			13	2			13		13				24	21	22.0	
65			9				9		9				34	25	28.7	
66			17			1	16		17				23	20	22.7	
67			41			5	36		41				27	28	27.5	0.7
68			15				15		15				27	20	23.6	
69			15			3	12		15				14	13	13.3	
70			4				4		4						22	
71			13			12	1		13						54	
72			9				9		9						13	
73		48,413	1,908	84	30	580	1,328	209	1,699							
74			41		6	1	40	1	40		1.40		29	16	26.8	
75	55,282	1,496	421	2	5	124	297		421		2.62		31	14	22.5	0.41
76	47,108	2,701	113	3	1	29	84	2	111				26	18	25	
77			153	3		97	56	2	151		1.50	SR	31	24	28.9	
78	187,185	12,639	234	16	1	64	170	37	197			RP	35	28	30.4	
79	6,781	614	50		1	4	46		50		3.20		29	15	21.8	
80	289,885	11,649	682	23	25	112	570	2	680		3.06		27	11	23.5	
81	85,465	2,954	289		2	70	219	26	263		1.39		38	14	22	
82	y		5		1		5		5				32	26	29	
83	842,381	17,046	1,257	8	21	33	1,224	1	1,256		4.68		32	12	25.1	
84	y		105		1		105		105				17	13	13.7	1.0
85	47,546	14,925	386	128	7	56	330	143	243		1.06		39	13	30	
86	47,288	1,563	175	1	18	9	166		175				24	11	21	2.7
87	y		17	3	1		17	7	10		1.56		48	33	43.9	
88	79,711	2,553	316	3	4	16	300		316		2.05		25	14	20.5	
89	97,065	13,937	148	31	5	10	138	47	101		1.00		42	31	33.2	
90	658,204	8,412	657	1	29	90	567	1	656		3.29	RP	38	28	32.5	
91	93,715	2,563	95	1		20	75	6	89		1.41	RP	29	16	23	
92	69,946	6,212	746	70	27	57	689	10	736		2.11		30	13	22	1.9
93	y		176	1	1	23	153		176				29	14	19	0.7
94	39,705	23,956	761	174	2	22	739	504	257		1.14		28	13	21	2.5
95		1,100	58	2		8	50		58							
96		124,320	6,885	470	158	845	6,040	785	6,096							
97								1,394	16,329							
							GAS FIELDS									
							Gas[c]									
98				1		2	2			2,500						
99	13,389	7,956					6									
100							1									
101	11,629	6,768		1			20			1,825						
102	y	319		1			4									
103	4,275	663			1		5									
104							1									
105				1			2									
106	2,244	794					6									
107	12,346	2,758			3		27			1,260	8.00					
108							3									
109	3,801	3,742		10			21									
110	1,416	372			2		22									
111	14,000						4									

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
55	Modelo		S		6,160	6,977	*y*	AF		7,200
56			S		858	1,569	*y*	A	Eoc	4,300
57	Sespe	Olig	S		400	1,651	*y*	A-S		3,595
58	Sespe	Olig	S		100	1,945	*y*	A		7,423
59	Meganos	Eoc	S		1,100	1,213	*y*	A		
60	Sespe	Olig	S		315	683	*y*	MF		3,934
61	Sespe	Olig	S		2,200	3,362	*y*	A	Eoc	6,702
62	Modelo	Mio	S		2,000	2,500	Fis	ML	Mio	
63	Sespe	Olig	S		500	995	*y*	A		2,956
64	Modelo	Mio	S		2,000	2,411	*y*	A		4,584
65	Repetto-Puente	Pli-Mio	S		500	2,605		MF		3,300
66	Puente	Mio	S		844	1,044		ML		
67	Vaqueros-Sespe	Mio-Olig			700	1,363		AF		2,500
68	Modelo	Mio			600	1,016		AF		4,400
69	Monterey	Mio	H		800	1,200		A	Schist	2,125
70	Monterey	Mio	S			2,900		S		
71	Purissima-Monterey	Pli, Mio	SH		1,379	1,600		ML	Mio	7,982
72	Monterey	Mio	S		900	1,500		AF		
73										
74	Repetto, Puente	Pli, Mio	S		4,635	5,810	1,825	AF	Mio	9,054
75	Repetto, Puente	Pli, Mio	S		260	3,026	800	AF	Mio	8,021
76	Repetto, Puente	Pli, Mio	S		2,450	3,607	153	A	Mio	9,084
77	Repetto, Puente	Pli, Mio	S		2,800	4,471	473	D	Mio	8,144
78	Repetto, Puente	Pli, Mio	S	28	3,800	5,189	1,900	D	Mio	10,435
79	Puente, Schist	Mio, Jur.	S	Fis	6,890	7,316	100	D	Franciscan schist	8,009
80	Repetto, Puente	Pli, Mio	S		1,900	4,009	*y*	AF	Mio	9,054
81	Repetto, Puente	Pli, Mio	S		1,073	2,597	1,165	AF	Mio	6,466
82	Repetto, Puente	Pli, Mio	S		6,375	5,841	*y*	MU	Mio	7,405
83	Repetto, Puente	Pli, Mio	S		2,377	5,264	2,000	AF	Mio	10,157
84	Repetto, Puente	Pli, Mio	S		475	1,045	*y*	AF	Mio	5,074
85	Repetto, Puente	Pli, Mio	S		1,730	4,422	*y*	A	Mio	8,468
86	Repetto, Puente	Pli, Mio	S	Fis	3,350	5,371	90	A	Franciscan schist	7,048
87	Repetto, Puente	Pli, Mio	S	29.4	3,640	5,605	400	AF	Mio	8,376
88	Repetto, Puente	Pli, Mio	S		2,900	4,057	300	A	Olig	10,496
89	Repetto, Puente	Pli, Mio	S	22	4,035	6,150	*y*	AF	Mio	10,389
90	Repetto, Puente	Pli, Mio	S	29	3,470	5,373	490	D	Mio	11,314
91	Repetto, Puente	Pli, Mio	S		4,314	5,441	200	A	Mio	9,054
92	Miocene	Mio	S	27.5	2,637	4,220	260	A	Franciscan schist	6,957
93	Repetto, Puente	Pli, Mio	S		200	2,109	270	MUF	Mio	5,040
94	Repetto, Puente		S	28	2,320	3,631	423	AF	Franciscan schist	6,814
95			S			2,314				
96										
97										
	GAS FIELDS									
98	Repetto	Pli	SH	26	3,880	4,900	110	A	Pli	7,708
99	Capay	Eoc	S		5,178	5,216	38	D	Cre	8,810
100	Cretaceous	Cre	S		3,235	3,265	30	D	Cre	5,334
101	Domengine-Tone	Eoc	S		3,800	4,344	170	AF	Cre	7,029
102	Cretaceous	Cre	S		2,700	5,855		MU	Intrusive rock	6,900
103	Cretaceous	Cre	S		3,926	4,070	100	D	Cre	9,690
104	Cretaceous	Cre	S		2,345	2,360	10	D	Cre	6,014
105	Cretaceous	Cre	S			3,682		A	Cre	
106	Etchegoin	Pli	S		4,177	5,219	223	A	Mio	11,186
107	Etchegoin	Pli	S		2,500	2,750	20	D	Pli	4,946
108	Eocene, Cretaceous	Eoc, Cre	S		2,611 7,900	2,923 8,125	63 140	D	Cre	8,377
109	Upper Pliocene	Pli	S		2,420	3,150	130	A	Mio	11,468
110	Upper Pliocene	Pli	S		2,275	3,215	15	A	Mio	9,700
111	Vaqueros	Mio	S		4,139	4,533	354	AF	Eoc	6,912

the area prospected. The discovery well, Western Gulf-Texas' K.C.L. No. 1, in the center of sec. 3, 32 S., 26 E., was brought in for 2200 bbl. of 55.5° gravity oil and 15,000,000 cu. ft. of gas. The well is producing from 122 ft. of net sand, which has an average porosity of 20 per cent and an average permeability of 135 millidarcys. The top portion of this sand body is predominately a gas sand of very low permeability. Only the upper portion of the Stevens zone (Miocene) has been penetrated in this well and undoubtedly later completions will cut off gas sands and produce oil with a low gas-oil ratio from the lower Stevens zone, as is done in the adjacent Coles Levee field. There is considerable uncertainty as to the type of structure and the productive area. This field is on the extension of the Elk Hills uplift or on an echelon fold.

Strand Field.—One mile northeast of the Canal field the Tide Water Associated Oil Co., in conjunction with the Continental Oil Co., discovered the Strand field when the Tide Water Associated Oil Co. brought in K.C.L. No. 35-E flowing 1306 bbl. of 34.1° gravity oil from the Stevens zone (Miocene) with bottom of hole at 8320 ft. The field has a closure of 100 ft. with an estimated productive area of 300 acres. The net average thickness of productive sand is 60 ft., its average porosity being 22 per cent and permeability 330 millidarcys.

EXTENSIONS AND DEEPER SAND DEVELOPMENTS

San Joaquin Valley District

Coalinga Nose Field.—The Coalinga Nose field, which was the most important discovery of 1938, was subjected to an intensive drilling campaign during the year 1939. Development indicates that between 2500 and 3000 acres will be productive, with an average sand thickness of 370 feet.

Coles Levee and Richfield Western Fields.—The Coles Levee field and the Richfield Western field (Tupman), which were discovered in November 1938, have been rapidly developed during the year. Further development will be needed before it can be ascertained whether these two fields, which are contiguous, are on the same structure. Production is obtained in both fields from overlapping beds in the upper Miocene, on the east-plunging nose of Elk Hills. At the present time the Coles Levee field has an indicated productive area of 2400 acres and the Richfield Western field, 700 acres. The ultimate productive area, if these two fields are on the same structure, will probably be more than 5000 acres.

Wasco Field.—The productive area of this deep field was increased to approximately 450 acres by the completion of George F. Getty's Jansen No. 1 on the north end of the field, at a depth in excess of 13,000 ft., with only 32 ft. of net productive sand.

COASTAL DISTRICT

The most important development in the Coastal district during the year was the extension of the Ventura Avenue field, both to the north and to the east, at depths ranging between 8000 and 11,000 ft. This field has the greatest sand thickness of any field in California, its 3000 ft. of sand exceeding the Long Beach field, with its maximum thickness of 2240 feet.

LOS ANGELES BASIN DISTRICT

Montebello Field (*West*).—More than a hundred wells have been completed in this field during the year. Development indicates a productive area of about 600 acres. The Eighth, or deepest zone, which has had its greatest development during the year, has 100 ft. net thickness of sand. A gas cap occupies the higher structural portions of this field. As there is very little evidence of edge-water encroachment, this gas cap has

TABLE 2.—*Summary of Drilling Operations in California*

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Sec.	Twp.	Rge.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Fresno	17	19S	16E	8,237	Middle Eocene	Amerada Petr. Corp.	4,230	14.2	44/64	2,000	2,000	Discovery, N. East Coalinga
2	Kern...	7	30S	26E	8,320	Upper Miocene	Continental Oil Co. and Tide Water Assoc. Oil Co.	1,042	0.62	½	200	200	Discovery, Strand field
3	Kern...	16	31S	29E	6,270	Chanac-Pliocene	Texas Superior and Standard Oil Co.	2,988	1.39	39/64 and 59/64	385	385	Discovery, Mountain View South
4	Kern...	3	32S	26E	10,178	Upper Miocene	Texas Co. and West Gulf Oil Co.	2,246	15	24/64	1,775	2,450	Discovery, Paloma field
5	Kern...	28	11N	20W	11,168	Oligocene	Richfield Oil Co.	Dry hole					Deep test Wheeler Ridge field
6	Kern...	7	29S	24E	11,506	Upper Miocene	Calif. Explor. Co.	Dry hole					Deep test South Buttonwillow
7	Kern...	6	30S	28E	10,427	Oligocene	Richfield Oil Co.	Dry hole					Deep test Union Avenue
8	Orange	8	4S	10E	8,977	Cretaceous	Texas Company	Dry hole					Anaheim
9	Kern...	12	29S	25E	11,510	Vedder (Miocene)	General Petr. Corp.	1,637	2.3	24/64	1,700	1,660	Extension of Greeley field
10	Kern...	1	29S	25E	14,018	Eocene	Superior Oil Co.	Dry hole					Deep test Rio Bravo field
11	Kern...	29	29S	27E	4,400	Pliocene	Richfield Oil Co.	127		On pump			S.W. Extension Fruitvale field
12	Kern...	14	30S	26E	14,051	Lower Miocene	Continental Oil Co.	Dry hole					Deep test East of Ten Section field
13	Kern...	1	32S	24E	10,614	Miocene	General Petr. Corp.	Dry hole					Deep test East Flank B. V. Hills

expanded very rapidly over the entire area of the field. In order to prevent underground and surface waste of gas, its production has been controlled by a court order under provisions of the California Gas Conservation Law. A formula has been used in curtailment of gas, which gives approximately equal withdrawal of reservoir volume to all wells. At the present time, under this formula, oil production of the field is less than that allotted by the Oil Umpire.

Wilmington Field.—The Wilmington field had more well completions during the year than any other field in the state. Development of the tideland reserves by slant drilling has been very successful, and results indicate that this type of drilling may continue over a number of years. The present productive area embraces approximately 4400 acres, with an average sand thickness of 490 ft., and is believed to contain, at present, the largest oil reserves of any field in the Los Angeles Basin and ranks about third on the basis of ultimate production.

CONCLUSION

Owing to the tendency of lower allotments to new maximum wells and consequent increased time of payout of drilling expenditure, a decrease in all drilling activity is anticipated for 1940.

The former need for increased reserves is now overshadowed by more necessary demand for present profits. Under the present system of curtailment, with the tendency of greater curtailment of large wells, giving less weight to potentials, reserves of oil in flush fields will have less present value because of the slower rate of withdrawal and greater deferment of revenue.

TABLE 3.—*California Oil-field Development Table*

Year	Number Drilling Notices Filed	Number Drilling Wells Abandoned	Number Producers Abandoned	Number Producers Completed (New Wells)	Percentage of Increase or Decrease[a]	Initial Production of New Wells, Daily Average, Bbl.	
						Per Well	Total
1929	1,256	314	212	910		1,437	1,307,496
1930	918	254	320	755	*17	775	584,521
1931	329	238	177	246	*67	1,481	364,434
1932	279	191	172	184	*25	852	156,823
1933	596	163	215	248	35	1,105	274,104
1934	631	247	200	449	81	1,190	534,508
1935	986	347	203	710	37	954	677,320
1936	1,102	320	208	786	11	471	370,227
1937	1,643	313	273	1,156	47	560	647,331
1938	1,162	265	252	994	*14	1,242	1,234,482
1939 (est.)	1,085	254	282	839	*15	1,322	1,108,800

[a] Decrease starred.

Oil and Gas Development in Illinois in 1939

By Alfred H. Bell,* Member A.I.M.E., and George V. Cohee†

(New York Meeting, February 1940)

In 1939 Illinois produced 94,302,000 bbl. of oil—almost three times the amount of oil produced at the peak in 1908, when development in the southeastern Illinois field was at its height (Fig. 1). It represents nearly a fourfold increase over the 24,075,000 bbl. produced in 1938 (Table 6).

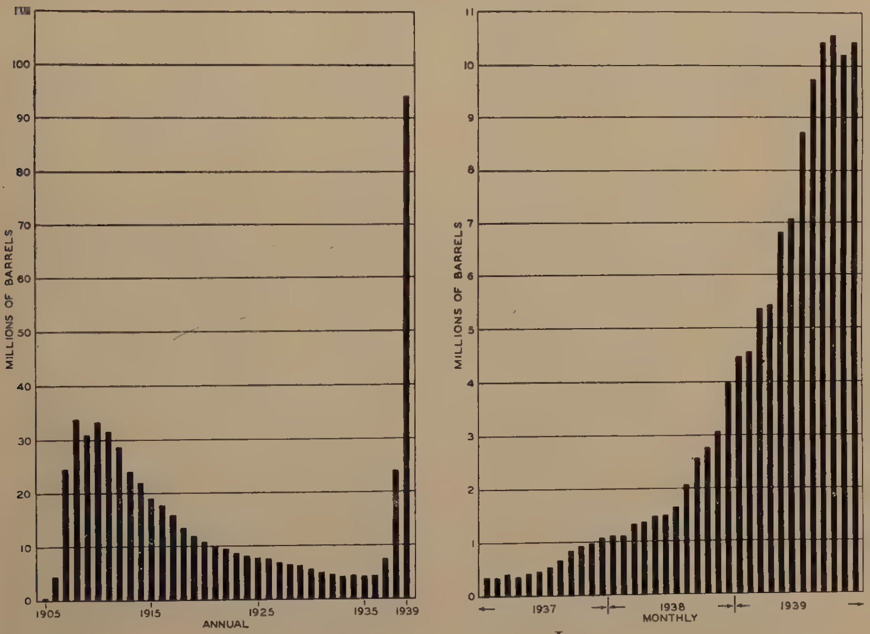

Fig. 1.—Production of oil in Illinois.

This rapid increase in oil production in Illinois is largely due to development in the Salem and Louden fields (Table 1). During 1939 daily production for the state increased from 135,000 to 332,572 bbl. A notable increase in production for 1940 is expected as a result of the drilling of the Devonian limestone in the Salem and Centralia fields,

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TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1939		End of 1939		
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
1	Warrenton-Borton, *Edgar*	1906	100	0	29,655	625	0	0	22	0	0	1	13	0
2	Westfield (Parker Twp.), *Clark, Coles*	1904	9,000	55	*x*	*x*	*x*	0	1,624	3	33	24	326	0
3			850	75	*x*	*x*	*x*	0	185	0	0	*y*	*y*	0
4			9,000	0	*x*	*x*	*x*	0	1,446	2	0	*y*	*y*	0
5			1,500	0	*x*	*x*	*x*	0	13	1	0	*y*	*y*	0
6	Siggins (Union Twp.), *Cumberland, Clark*	1906	3,580	75	*x*	*x*	*x*	0	995	0	51	0	863	0
7			3,135	55	*x*	*x*	*x*	0	854	0	*y*	0	*y*	0
8			435	15	*x*	*x*	*x*	0	90	0	*y*	0	*y*	0
9			855	105	*x*	*x*	*x*	0	192	0	*y*	0	*y*	0
10	York, *Cumberland*........	*y*	310	40	*x*	*x*	*x*	0	70	0	0	0	44	0
11	Casey, *Clark*............	1906	1,925	55	*x*	*x*	*x*	0	532	0	0	0	488	0
12			190	15	*x*	*x*	*x*	0	41	0	0	0	*y*	0
13			400	0	*x*	*x*	*x*	0	82	0	0	0	*y*	0
14			1,525	15	*x*	*x*	*x*	0	319	0	0	0	*y*	0
15	Martinsville, *Clark*.......	1907	710	155	*x*	*x*	*x*	0	213	0	0	0	122	0
16			15	20	*x*	*x*	*x*	0	7	0	0	0	*y*	0
17			275	35	*x*	*x*	*x*	0	63	0	0	0	*y*	0
18			105	0	*x*	*x*	*x*	0	21	0	0	0	*y*	0
19			170	0	*x*	*x*	*x*	0	34	0	0	0	*y*	0
20			195	0	*x*	*x*	*x*	0	39	0	0	0	*y*	0
21			5	0	*x*	*x*	0	0	1	0	0	0	*y*	0
22	North Johnson, *Clark*....	1907	1,320	20	*x*	*x*	*x*	*x*	485	0	15	21	412	0
23			1,115	0	*x*	*x*	*x*	*x*	296	0	*y*	*y*	*y*	0
24			160	0	*x*	*x*	*x*	*x*	32	0	*y*	*y*	*y*	0
25			820	5	*x*	*x*	*x*	*x*	177	0	*y*	*y*	*y*	0
26			215	0	*x*	*x*	0	0	44	0	*y*	*y*	*y*	0
27	South Johnson, *Clark*.....	1907	1,715	65	*x*	*x*	*x*	*x*	535	1	8	0	479	0
28			185	5	*x*	*x*	*x*	*x*	38	0	*y*	0	*y*	0
29			295	0	*x*	*x*	*x*	*x*	59	0	*y*	0	*y*	0
30			1,675	35	*x*	*x*	*x*	*x*	402	1	*y*	0	*y*	0
31			845	5	*x*	*x*	*x*	*x*	170	0	*y*	0	*y*	0
32	Bellair, *Crawford, Jasper*	1907	1,300	5	*x*	*x*	*x*	*x*	486	1	9	0	395	0
33			1,165	0	*x*	*x*	*x*	*x*	310	1	*y*	0	*y*	0
34			315	0	*x*	*x*	*x*	*x*	65	0	*y*	0	*y*	0
35			910	0	*x*	*x*	*x*	*x*	182	0	*y*	0	*y*	0
36	Clark County Division[1]		19,960	475	52,388,000	283,000	*x*	*y*	4,987	5	116	46	3,142	0
37	Main,[2] *Crawford*.........	1906	35,135	515	*x*	*x*	*x*	*x*	7,322	0	198	243	4,912	0
38			340	0	*x*	*x*	*x*	*x*	68	0	*y*	*y*	*y*	0
39			33,795	510	*x*	*x*	*x*	*x*	7,141	0	*y*	*y*	*y*	0
40			1,000	0	*x*	*x*	*x*	*x*	108	0	*y*	*y*	*y*	0
41	New Hebron, *Crawford*...	1909	1,350	210	*x*	*x*	*x*	*x*	297	1	5	1	173	0
42	Chapman, *Crawford*......	1914	1,045	515	*x*	*x*	*x*	*x*	193	0	4	0	68	0
43	Parker, *Crawford*.........	1907	1,310	30	*x*	*x*	*x*	*x*	256	0	0	0	221	0
44	Allison-Weger, *Crawford*..	*y*	1,075	20	*x*	*x*	*x*	*x*	147	1	1	0	65	0
45	Flat Rock,[3] *Crawford*.....	*y*	1,375	545	*x*	*x*	*x*	*x*	289	0	6	1	143	0
46	Birds, *Crawford, Lawrence*	*y*	4,370	115	*x*	*x*	*x*	*x*	684	0	14	6	459	0

[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.

[2] Includes Kibbie, Oblong, Robinson, and Hardinsville.

[3] Includes Swearingen gas.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.[26]		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity, A.P.I. at 60°F.,[27] Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	0	13	x	x		x	x	Unnamed	Pen	S	Por	159	215	x	ML	Pen	715
2	0	326	200±	x		34.0	x	See below							D	Trenton	2,918
3	0	y	x	x		30.0	x	Shallow gas sand	Pen	S	Por	281	376	36	D		
4	0	y	x	x		33.5	x	Westfield lime	MisL	L	Cav	334	446	x	D	St. Peter	3,009
5	0	y	x	x		37.0	x	Trenton	Ord	L	Por	2,265	2,568	x	D		
6	0	863	x	x	RP	33.0	x	See below							D	Devonian	2,010
7	0	y	x	x		34.0	x	First Siggins sand	Pen	S	Por	367	465	x	D		
8	0	y	x	x		(33.6)*	x	Second and third Siggins sand	Pen	S	Por	478	562	x	D		
9	0	y	x	x		(25.7)	x	Lower Siggins sand	Pen	S	Por	556	590	x	D		
10	0	44	x	x		(30.3)	x	York sand	Pen	S	Por	588	680	x	AM		960
11	0	488	x	x	RP	29.2	x	See below							AM	MisL	808
12	0	y	x	x		(31.9)	x	Upper gas sand	Pen	S	Por	263	358	x	AM		
13	0	y	x	x		(30.1)	x	Lower gas sand	Pen	S	Por	309	426	x	AM		
14	0	y	x	x		(33.6)	x	Casey sand	Pen	S	Por	444	505	x	AM		
15	0	122	x	x		36.8	x	See below							D	St. Peter	3,411
16	0	y	x	x		y	x	Shallow sand	Pen	S	Por	255	411	x	D		
17	0	y	x	x		y	x	Casey sand	Pen	S	Por	449	511	x	D		
18	0	y	x	x		y	x	Martinsville	MisL	L	Por	477	506	x	D		
19	0	y	x	x		(38.9)	x	Carper	MisL	S	Por	1,340	1,418	x	D		
20	0	y	x	x		y	x	"Niagaran"	Dev	L	Por	1,553	1,596	x	D		
21	0	y	x	x		(39.6)	x	Trenton	Ord	L	Por	2,708	2,830	x	D		
22	0	412	x	x		31.0	x	See below							AM	Mis	965
23	0	y	x	x		y	x	Claypool sand	Pen	S	Por	416	486	x	AM		
24	0	y	x	x		y	x	Shallow sands	Pen	S	Por	314	451	x	AM		
25	0	y	x	x		y	x	Casey sand	Pen	S	Por	465	508	x	AM		
26	0	y	x	x		y	x	Upper Partlow	Pen	S	Por	534	554	x	AM		
27	0	479	x	x		32.2	x	See below							AM	Mis	1,160
28	0	y	x	x		y	x	Clay pool sand	Pen	S	Por	392	549	x	AM		
29	0	y	x	x		y	x	Casey sand	Pen	S	Por	453	518	x	AM		
30	0	y	x	x		y	x	Upper Partlow	Pen	S	Por	489	570	x	AM		
31	0	y	x	x		28.5	x	Lower Partlow	Pen	S	Por	598	618	x	AM		
32	0	395	x	x	RP	33.7		See below							AM	MisL	1,471
33	0	y	x	x		(32.4)	x	"500 Ft." sand	Pen	S	Por	561	726	x	AM		
34	0	y	x	x		y	x	"800 Ft." sand	Pen	S	Por	817	907	x	AM		
35	0	y	x	x		(37.0)	x	"900 Ft." sand	MisU	S	Por	886	920	x	AM		
36	0	3,142	x	x		33.0	x							33±			
37	0	4,912	425±	y	RP	33.0	x	See below								Trenton	4,620
38	0	y	x	x		y	x	Shallow sand	Pen	S	Por	508	822	x	ML		
39	0	y	x	x		32.8	x	Robinson sand	Pen	S	Por	900	960	25±	ML	Trenton	4,620
40	0	y	x	x		y	x	Oblong	Mis	S, L	Por	1,337	1,416	x	A, ML	Mis	1,479
41	0	173	x	x	RP	30.1	x	Robinson sand	Pen	S	Por	940	975	x	ML	MisL	2,056
42	0	68	x	x		y	x	Robinson sand	Pen	S	Por	995	1,015	x	ML	Mis	2,279
43	0	221	x	x		y	x	Robinson sand	Pen	S	Por	1,000	1,025	x	ML	Pen	1,127
44	0	65	x	x		29.5	x	Robinson sand	Pen	S	Por	912	930	x	ML	Pen	1,041
45	0	143	x	x		22.5	x	Robinson (Flat Rock)	Pen	S	Por	935	945	x	ML	Pen	1,032
46	0	459	x	x	RP	31.8	x	Robinson sand	Pen	S	Por	930	950	x	ML	MisL	1,731

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[26] Pressures in the southeastern Illinois oil fields are estimated bottom-hole pressures reported in previous Survey publications.

[27] All gravities given prior to 1936 (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey *Bull.* 54, Table 3. The values have been converted from Baumé to A.P.I. gravities.

* See footnote 27.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
47	Crawford County Division[4]		45,655	1,945	144,682,000	1,063,000	*x*	*y*	9,195	2	228	251	6,041	0
48	Lawrence, *Lawrence, Crawford*	1906	24,150	1,550	*x*	*x*	*x*	*x*	4,401	3	23	116	3,167	0
49			5,015	35	*x*	*x*	*x*	*x*	1,232	1	*y*	*y*	*y*	0
50			2,240	0	*x*	*x*	*x*	*x*	475	0	*y*	*y*	*y*	0
51			345	1,095	*x*	*x*	*x*	*x*	243	0	*y*	*y*	*y*	0
52			15,960	220	*x*	*x*	*x*	*x*	3,017	0	*y*	*y*	*y*	0
53			4,020	200	*x*	*x*	*x*	*x*	685	1	*y*	*y*	*y*	0
54			6,950	0	*x*	*x*	*x*	*x*	958	1	*y*	*y*	*y*	0
55	St. Francisville, *Lawrence*	*y*	420	0	*x*	*x*	*x*	*x*	55	0	0	0	45	0
56	Lawrence County Division[5]		24,570	1,550	224,436,000	1,304,000	*x*	*y*	4,462	3	23	116	3,212	0
57	Allendale, *Wabash*	1912	1,680	0	4,743,000	87,000	*x*	*y*	427	0	1	0	325	0
58	Total southeastern fields[6]		91,855	3,970	426,278,655	2,737,625	*x*	*y*	19,074	10	368	413	12,720	0
59	Ayers Gas, *Bond*	1922	0	325	0	0	180.6	13.6	19	0	1	0	0	6
60	Greenville Gas, *Bond*	1910[7]	0	160	0	0	990.0	0	4	0	0	0	0	0
61	Bartelso, *Clinton*	1936	200	0	360,570	107,000	0	0	39	3	0	0	39	0
62		1939	10	0	3,000	3,000	0	0	1	1	0	0	1	0
63	Carlyle, *Clinton*	1911	915	0	3,373,400	29,000	0	0	165	0	0	25	78	0
64	Frogtown, *Clinton*	1918[8]	300	0	*x*	0	0	0	12	0	0	0	0	0
65	Ava-Campbell Hill, *Jackson*	1917[9]	70	370	25,000	0	*x*	0	35	0	0	0	0	0
66	Colmar-Plymouth, *McDonough, Hancock*	1913	2,450	0	2,551,970	136,000	*x*	*y*	478	1	0	72	210	0
67	Decatur, *Macon*	1937[10]	10	0	1,000	0	0	0	2	0	0	2	0	0
68	Carlinville, *Macoupin*	1909[11]	30	50	*x*	0	*x*	0	8	0	0	0	0	0
69	Gillespie-Benld Gas, *Macoupin*	1923[12]	0	80	0	0	135.8	0	4	0	0	0	0	0
70	Gillespie-Wyen, *Macoupin*	1915	40	0	*x*	0	0	0	22	0	0	12	0	0
71	Spanish Needle Creek Gas, *Macoupin*	1915[13]	0	80	0	0	14.4	0	7	0	0	0	0	0
72	Staunton Gas, *Macoupin*	1916[14]	0	400	0	0	1,050	0	18	0	0	0	0	0
73	Collinsville, *Madison*	1909[15]	40	0	850	135	0	0	6	1	1	0	0	0
74	Brown-Languish Kuester-Junction City, *Maricn*	1910	175	0	*x*	*y*	0	0	12	0	0	0	5	0
75			20	0	*x*	*y*	0	0	10	0	0	0	4	0
76	Sandoval, *Marion*	1909	770	0	2,665,800	20,000	0	0	123	0	0	0	37	0
77		1938	135	0	794,000	794,000	0	0	22	21	0	0	22	0
78	Wamac, *Marion, Clinton, Washington*	1921	250	0	403,530	21,000	0	0	104	0	3	0	43	0
79	Litchfield, *Montgomery*	1879[16]	100	0	22,000	0	0	0	18	1	0	1	0	0

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[4] Total of lines 37, 41, 42, 43, 44, 45, 46.

[5] Total of lines 48 and 55.

[6] Total of lines 36, 47, 56, 57.

[7] Abandoned 1923.

[8] Abandoned 1933.

[9] Abandoned 1934.

[10] Wells drilled in 1922 and 1924, first production in 1937.

[11] Abandoned 1925±.

[12] Abandoned 1935.

[13] Abandoned 1934.

[14] Abandoned 1919.

[15] Abandoned 1921, one well completed and abandoned in 1939.

[16] Abandoned 1904, one well completed and shut down in 1939.

which began in December 1939. This development has focused interest on Devonian possibilities in both old and new fields that are producing from younger formations.

Of a total of 3675 wells completed in 1939 in Illinois, 2946 produced oil, 24 produced gas and 705 were dry holes. Of the total, 478 are classified as "wildcat" wells, defined as wells drilled outside of proved territory and more than one mile from the nearest production. The remainder, or 3197, were drilled in or near proved fields.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1939: Number of Wells		Reservoir Pressure, Lb. per Sq. In.[28]		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity, A.P.I. at 60°F.,[27] Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.: Top Prod. Zone	Depth, Avg. Ft.: Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
47	0	6,041	425±	*x*		32.3	*x*		Pen, Mis	S	Por				ML	Trenton	4,620
48	0	3,167	650±	*x*	RP	32.9	*x*	See below							A	St. Peter	5,190
49	0	*y*	*x*	*y*		*y*	*x*	Bridgeport sand	Pen	S	Por	800	1,000	40	A		
50	0	*y*	*x*	*x*		*y*	*x*	Buchanan	Pen	S	Por	1,250	1,265	15	A		
51	0	*y*	*x*	*x*		*y*	*x*	"Gas" sand	MisU	S	Por	1,330	1,345	15	A		
52	0	*y*	600±	*x*		*y*	*x*	Kirkwood	MisU	S	Por	1,400	1,430	30	A		
53	0	*y*	650	*x*		*y*	*x*	Tracey	MisU	S	Por	1,560	1,580	20	A		
54	0	*y*	*x*	*x*		*y*	*x*	McClosky ✓	MisL	L	Por	1,700	1,710	10	A		
55	0	45	600	*x*		37.3	*x*	Kirkwood	MisU	S	Por	1,843	1,865	22	ML	Mis	1,900
56	0	3,212	*x*	*x*												St. Peter	5,190
57	0	325	*x*	*x*	RP	35.1		Biehl sand	Pen	S	Por	1,425	1,460	20	AM	MisL	2,367
58	0	12,720															
59	0	0	335	225				Lindley (2d)	MisU	S	Por	940	945	5	A	MisL	1,150
60	0	0	*x*	*x*				Lindley (1st, 2d)	MisU	S	Por	927	993	*x*	A	Mis	1,065
61	0	39	*x*	*x*		36.2	0.20	Carlyle	MisU	S	Por	984	1,008	24	D	Devonian	2,431
62	0	1	*x*	*x*		41.5	0.27	Devonian	Dev	L	Por	2,416	2,431	14	D	Devonian	2,431
63	0	78	*x*	*x*	RP	35.2	0.26	Carlyle	MisU	S	Por	1,035	1,055	20	A	Silurian	2,620
64	0	0	*x*	*x*		31.9	*x*	Carlyle	MisU	S	Por	950	957	7	D	Cypress	962
65	0	0	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	780	798	18	A	Devonian	2,530
66	0	210	*x*	*x*	RP	37.6	0.38	Hoing sand	Dev	S	Por	447	468	21	A	Trenton	805
67	0	0	*x*	*x*		39.5	*x*	"Niagaran"	Dev	L	Por	2,020	2,076	30	N	St. Peter	2,991
68	0	0	135	*x*		27.7	*x*	Unnamed	Pen	S	Por	380	398	*x*	A	Pen	410
69	0	0	155	*x*				Unnamed	Pen	S	Por	542	555	*x*	A	Pen	575
70	0	0	*x*	*x*		30.0	*x*	Unnamed	Pen	S	Por	650	670	*x*	T	Trenton	2,560
71	0	0	*x*	*x*				Unnamed	Pen	S	Por	305	405	*x*	D	Pen	495
72	0	0	145	*x*				Unnamed	Pen	S	Por	461	491	*x*	A	Trenton	2,371
73	0	0	*x*	*x*		*x*	*x*	Devonian-Silurian	Dev-Sil	L	Por	1,305	1,400	20	L	Silurian	1,500
74	0	5	*x*	*x*		32.0	*x*	Dykstra, Wilson	Pen	S	Por	1,130	1,150	20	D	MisL	2,001
75	0	4	*x*	*x*		32.0	*x*	Cypress	MisU	S	Por	1,658	1,673	15	ML	Devonian	3,344
76	0	37	*x*	*x*		34.5	*x*	Benoist	MisU	S	Por	1,540	1,560	20±	D	Devonian	3,055
77	3	19	*y*	*y*		38.0	0.38	Devonian	Dev	L	Por	2,924	2,969	9	D	Devonian	3,055
78	0	43	*x*	*x*		30.2	*x*	Petro	Pen	S	Por	720	760	20	D	MisL	1,760
79	0	0	*x*	*x*		21.7	*x*	Unnamed	Pen	S	Por	664	674	*x*	D	Pen	681

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1939		End of 1939		
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
80	Waterloo, *Monroe*	1920[17]	125	0	176,000	10,000	0	0	30	7	0	0	7	0
81	Jacksonville Gas, *Morgan*	1910[18]	30	1,290	2,100	0	*x*	0	53	0	0	0	0	0
82	Pike County Gas, *Pike*	1905[19]	0	8,960	0	0	*x*	0	68	0	0	0	0	0
83	Sparta, *Randolph*	1888[20]	65	100	*x*	0	*x*	0	20	0	0	0	0	0
84	Dupo, *St. Clair*	1928	670	0	1,092,870	146,000	0	0	263	21	1	0	49	0
85	Total for fields prior to Jan. 1, 1937[21]		98,095	15,785	437,750,745	4,003,760	2,370.8	13.6	20,617	66	374	523	13,215	6
86	Sorento, *Bond*	1938	10	0	*y*	*y*	0	0	1	0	0	0	1	0
87	Flora, *Clay*	1938	290	0	214,000	147,000	0	0	17	8	0	0	17	0
88			10	0	*x*	*x*	0	0	1	1	0	0	1	0
✓ 89			290	0	*x*	*x*	0	0	16	7	0	0	16	0
90	Iola, *Clay*	1939	20	0	*y*	*y*	0	0	2	2	0	0	2	0
✓ 91	Clay City, *Clay, Wayne*	1937	7,930	0	11,895,000	6,336,000	0	0	379	157	4	6	369	0
92	Hoffman, *Clinton*	1939	10	0	*y*	*y*	0	0	1	1	0	0	1	0
93	Centralia, *Clinton, Marion*	1937	2,190	0	5,922,000	2,895,000	0	0	553	27	14	0	539	0
94			30	0	*x*	*x*	0	0	21	9	0	0	21	0
95			2,190	0	*x*	*x*	0	0	531	17	14	0	517	0
96			10	0	*x*	*x*	0	0	1	1	0	0	1	0
97	Mattoon, *Coles*	1939[22]	10	0	*y*	*y*	0	0	1	1	1	0	0	0
98	Cowling, *Edwards*	1939	100	0	25,000	25,000	0	0	11	11	0	0	11	0
99	Grayville, *Edwards, White*	1939	70	0	30,000	30,000	0	0	8	8	0	0	8	0
100	Louden, *Fayette*	1937	16,370	0	20,237,000	18,345,000	0	0	1,334	843	3	2	1,329	0
101			*y*	0	*x*	*x*	0	0	630	377	3	0	627	0
102			*y*	0	*x*	*x*	0	0	283	265	0	0	283	
103			*y*	0	*x*	*x*	0	0	421	201	0	2	419	0
104	St. James, *Fayette*	1938	1,030	0	494,000	445,000	0	0	76	52	0	0	76	0
105	Whittington, *Franklin*	1939	10	0	*y*	*y*	0	0	1	1	0	0	1	0
106	Junction, *Gallatin*	1939	60	0	*y*	*y*	0	0	6	6	0	0	6	0
107	Cravat, *Jefferson*	1939	100	0	14,000	14,000	0	0	6	6	0	0	6	0
108	Dix, *Jefferson*	1938	1,250	0	*y*	*y*	0	0	57	22	0	0	57	0
109	Elk Prairie, *Jefferson*	1938	10	0	*y*	*y*	0	0	1	0	0	0	1	0
110	Ina, *Jefferson*	1938	10	0	*y*	*y*	0	0	1	0	0	0	1	0
111	Marcoe, *Jefferson*	1938	10	0	*y*	*y*	0	0	2	1	1	0	1	0
112	Roaches, *Jefferson*	1938	110	0	70,000	70,000	0	0	9	7	0	0	9	0
113			*y*	0	*x*	*x*	0	0	4	3	0	0	4	0
114			110	0	*x*	*x*	0	0	5	4	0	0	5	0
115	Russellville gas, *Lawrence*	1937	0	1,020	0	0	1,065.1	963.7	32	18	0	0	0	32
116			0	20	0	0	*y*	*y*	4	2	0	0	0	4
117			0	1,000	0	0	*y*	*y*	28	16	0	0	0	28
118	Patoka, *Marion*	1937	720	0	1,661,000	494,000	0	0	115	0	11	0	104	0
119			710	0	*x*	*x*	0	0	114	0	11	0	103	0
120			10	0	*x*	*x*	0	0	1	0	0	0	1	0
121	Salem, *Marion*	1938	8,870	0	52,619,000	49,724,000	0	0	1,581	1,088	4	17	1,560	0
122			*y*	0	*x*	*x*	0	0	884	442	4	15	865	0
123			*y*	0	*x*	*x*	0	0	141	120	0	0	141	0
124			*y*	0	*x*	*x*	0	0	544	524	0	2	542	0
125			*y*	0	*x*	*x*	0	0	5	5	0	0	5	0
126			*y*	0	*x*	*x*	0	0	7	7	0	0	7	0
127	Tonti, *Marion*	1939	270	0	910,000	910,000	0	0	35	35	0	0	35	0
128			*y*	0	*x*	*x*	0	0	4	4	0	0	4	0
129			*y*	0	*x*	*x*	0	0	4	4	0	0	4	0

[17] Abandoned 1930, revived 1939.

[18] Abandoned 1937.

[19] Abandoned 1930.

[20] Abandoned 1900.

[21] Total of lines 58 to 81 inclusive.

[22] Abandoned 1939.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.[28]		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity, A.P.I. at 60°F.,[27] Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
80	0	7	x	x		30.0	x	Trenton	Ord	L	Por	410	460	50	A	Trenton	845
81	0	0	x	x		x	x	Gas sand	Pen	S, SL	Por	330	335	5	ML	Trenton	1,390
82	0	0	x	x				"Niagaran"	Sil	L	Por	265	275	10	A	St. Peter	893
83	0	0	x	x		x	x	Cypress	MisU	S	Por	850	857	7	D	MisU	985
84	0	49	x	x		32.7	0.70	Trenton	Ord	L	Por	601	651	50	A	Trenton	819
85	3	13,212															
86	0	1	x	x		x	x	Devonian	Dev	L	Por	1,800	1,830	y	D	Devonian	1,830
87	0	17													D	MisL	3,100
88	0	1	x	x		37.4	x	Bethel	MisU	S	Por	2,788	2,800	12			
89	0	16	x	x		38.5	x	McClosky ✓	MisL	L	Por	2,965	2,978	6			
90	0	2	x	x		x	x	Aux Vases	MisU	S	Por	2,335	2,351	4	D	MisU	2,383
✓ 91	5	364	x	x	PM	38.5	x	McClosky ✓	MisL	L	Por	2,995	3,058	9	A	MisL	3,197
92	0	1	x	x		x	x	Bethel	MisU	S	Por	1,324	1,329	5	D	MisL	1,567
93	0	539													A	Devonian	2,933
94	0	21	x	x		36.4	x	Cypress	MisU	S	Por	1,200	1,225	19			
95	0	517	x	x		37.4	x	Bethel	MisU	S	Por	1,355	1,378	23			
96	0	1	x	x		x	x	Devonian	Dev	L	Por	2,884	2,933	8			
97	0	0	x	x		44.1	0.16	Cypress	MisU	S	Por	1,835	1,919	25	A?	Devonian	3,307
98	0	11	x	x		37.0	0.38	Cypress	MisU	S	Por	2,626	2,640	15	D	MisL	3,175
99	0	8	x	x		36.0	0.31	McClosky	MisL	L	Por	3,093	3,188	6	D?	MisL	3,269
100	361	968			PM										A	Devonian	3,170
101	122	505	x	472		38.5	0.25	Cypress	MisU	S	Por	1,493	1,549	25			
102	96	187	x	406		38.5	x	Stray	MisU	S	Por	1,546	1,571	17			
103	143	276	x	474		38.5	x	Bethel	MisU	S	Por	1,540	1,561	18			
104	0	76	x	500		37.0	0.31	Cypress	MisU	S	Por	1,581	1,600	16	A	Devonian	3,375
105	0	1	x	x		40.0	x	McClosky and Rosiclare	MisL	L	Por	2,869	2,878	9	D	MisL	3,068
106	0	6	x	x		37.2	0.22	Waltersburg	MisU	S	Por	1,763	1,804	15	D	MisL	2,711
107	0	6	x	x		36.0	x	Bethel	MisU	S	Por	2,066	2,076	11	D	MisL	2,356
108	0	57	x	495	PM	38.0	x	Bethel	MisU	S	Por	1,948	1,959	14	A	Devonian	3,650
109	0	1	x	x		x	x	McClosky	MisL	L	Por	2,718	2,751	7	D	MisL	2,958
110	0	1	x	x		x	x	St. Louis	MisL	L	Por	3,002	3,007	5	D	MisL	3,064
111	0	1	x	x		28.0	x	McClosky	MisL	L	Por	2,746	2,765	11	D	MisL	3,066
112	0	9													D	MisL	2,285
113	0	4	x	x		37.0	x	Rosiclare	MisL	S	Por	2,187	2,200	14			
114	0	5	x	x		37.0	x	McClosky	MisL	L	Por	2,241	2,257	8			
115			380+	335											A	Devonian	3,133
116			y	y				Pennsylvanian	Pen	S	Por	619	831	12			
117			y	y				Buchanan	Pen	S	Por	1,078	1,119	10			
118	0	104													A	MisL	1,702
119	0	103	x	x		39.5	x	Bethel	MisU	S	Por	1,424	1,440	16			
120	0	1	x	x		40.9	x	Rosiclare	MisL	S	Por	1,562	1,612	33			
121	260	1,300			PM										A	Devonian	3,502
122	183	682	x	272		39.0	0.22	Benoist	MisU	S	Por	1,797	1,835	35			
123	11	130	x	335		38.6	0.21	Aux Vases	MisU	S	Por	1,813	1,865	28			
124	57	485	x	360		39.0	x	McClosky ✓	MisL	L	Por	1,975	2,048	17			
125	2	5	x	250		37.2	x	Salem	MisL	L	Por	2,177	2,254	17			
126	7	0	x	x		42.1	0.28	Devonian	Dev	L	Por	3,343	3,441	30			
127	0	35													D	Devonian	3,547
128	0	4	x	x		x	x	Bethel	MisU	S	Por	1,928	1,942	14			
129	0	4	x	x		37.0	x	Aux Vases	MisU	S	Por	2,003	2,038	26			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
130			270	0	*x*	*x*	0	0	27	27	0	0	27	0
131	Fairman, *Marion, Clinton*	1939	160	0	*y*	*y*	0	0	11	11	0	0	11	0
132	Dundas, *Richland*........	1939	400	0	*y*	*y*	0	0	18	18	0	0	18	0
133	Noble, *Richland*..........	1937	3,540	0	6,852,000	1,674,000	0	0	220	69	8	2	210	0
134			920	0	*x*	*x*	0	0	49	43	0	1	48	0
135			2,620	0	*x*	*x*	0	0	171	26	8	1	162	0
136	Olney, *Richland*..........	1937	510	0	753,000	338,000	0	0	36	6	0	0	36	0
137	Schnell, *Richland*........	1938	40	0	*y*	*y*	0	0	4	0	0	0	4	0
138	Stewardson, *Shelby*.......	1939	10	0	*y*	*y*	0	0	1	1	0	0	1	0
139	Griffin, *Wabash*..........	1939	690	0	169,000	169,000	0	0	47	47	0	0	47	0
140			*y*	0	*x*	*x*	0	0	4	4	0	0	4	0
141			*y*	0	*x*	*x*	0	0	41	41	0	0	41	0
142			*y*	0	*x*	*x*	0	0	2	2	0	0	2	0
143	East Keensburg, *Wabash*	1939	10	0	*y*	*y*	0	0	1	1	0	0	1	0
144	Keensburg, *Wabash*......	1939	700	0	783,000	783,000	0	0	120	120	0	0	120	0
145			*y*	0	*x*	*x*	0	0	3	3	0	0	3	0
146			*y*	0	*x*	*x*	0	0	117	117	0	0	117	0
147	Mt. Carmel, *Wabash*.....	1939	20	0	*y*	*y*	0	0	2	2	0	0	2	0
148	Cordes, *Washington*......	1939	1,090	0	468,000	468,000	0	0	95	95	0	0	95	0
149	Dubois, *Washington*......	1939	10	0	*y*	*y*	0	0	1	1	0	0	1	0
150	Barnhill, *Wayne*..........	1939	750	0	593,000	593,000	0	0	41	41	0	0	41	0
151	Boyleston, *Wayne*.......	1938	450	0	218,000	218,000	0	0	25	24	0	0	25	0
152	Cisne, *Wayne*...........	1937	960	0	*y*	*y*	0	0	47	21	0	1	46	0
153			*y*	0	*x*	*x*	0	0	2	0	0	0	2	0
154			*y*	0	*x*	*x*	0	0	1	1	0	0	1	0
155			960	0	*x*	*x*	0	0	44	20	0	0	44	0
156	Enterprise, *Wayne*.......	1939	1,450	0	1,269,000	1,269,000	0	0	50	50	0	0	50	0
157			*y*	0	*x*	*x*	0	0	1	1	0	0	1	0
158			1,450	0	*x*	*x*	0	0	49	49	0	0	49	0
159	Goldengate, *Wayne*......	1939	30	0	*y*	*y*	0	0	3	3	0	0	3	0
160	Leech Twp., *Wayne*......	1938	240	0	105,000	96,000	0	0	9	7	0	0	9	0
161	Mt. Erie, *Wayne*.........	1938	10	0	*y*	*y*	0	0	1	0	0	0	1	0
162	North Aden, *Wayne*......	1938	1,230	0	1,030,000	725,000	0	0	60	20	0	0	60	0
163	Rinard, *Wayne*..........	1937[23]	10	0	*y*	*y*	0	0	1	0	1	0	0	0
164	South Mt. Erie, *Wayne*...	1939	10	0	*y*	*y*	0	0	1	1	0	0	1	0
165	Aden, *Wayne, Hamilton*..	1938	200	0	*y*	*y*	0	0	5	1	0	0	5	0
166	Calvin, *White*...........	1939	20	0	*y*	*y*	0	0	2	2	0	0	2	0
167			10	0	*x*	*x*	0	0	1	1	0	0	1	0
168			10	0	*x*	*x*	0	0	1	1	0	0	1	0
169	Mill Shoals, *White*.......	1939	400	0	127,000	127,000	0	0	22	22	0	0	22	0
170			*y*	0	*x*	*x*	0	0	13	13	0	0	13	0
171			400	0	*x*	*x*	0	0	9	9	0	0	9	0
172	New Harmony, *White*....	1939	130	0	*y*	*y*	0	0	11	11	0	0	11	0
173			120	0	*x*	*x*	0	0	10	10	0	0	10	0
174			10	0	*x*	*x*	0	0	1	1	0	0	1	0
175	Phillipstown, *White*......	1939	20	0	*y*	*y*	0	0	2	2	0	0	2	0
176			10	0	*x*	*x*	0	0	1	1	0	0	1	0
177			10	0	*x*	*x*	0	0	1	1	0	0	1	0
178	Stokes, *White*...........	1939	140	0	60,000	60,000	0	0	7	7	0	0	7	0
179	Storms, *White*...........	1939	510	30	31,000	31,000	*x*	*x*	17	17	0	0	14	3
180	Total for fields after[24] Jan. 1, 1937		53,190	1,050	113,548,000	90,299,000	1,065.1	963.7	5,089	2,906	47	28	4,979	35
181	Total for Illinois[25]...		151,285	16,835	551,298,000	94,302,000	3,435.9	977.3	25,706	2,970	421	551	18,194	41

[23] Abandoned 1939.

[24] Total of lines 86 to 179 inclusive.

[25] Total of lines 85 and 180.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.[26]		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity, A.P.I. at 60°F.,[27] Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
130	0	27	*x*	*x*		39.4	0.21	McClosky	MisL	L	Por	2,134	2,165	12			
131	0	11	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	1,433	1,440	7	D	MisL	1,718
132	18	0	*x*	1,100		*x*	*x*	McClosky	MisL	L	Por	2,842	2,909	13	A	MisL	2,980
133	0	210													A	MisL	3,201
134	0	48	*x*	*x*		35.0	*x*	Cypress	MisU	S	Por	2,544	2,639	17			
135	0	162	*x*	*x*		40.0	*x*	McClosky	MisL	L	Por	2,957	3,003	10			
136	0	36	*x*	25		40.0	*x*	McClosky	MisL	L	Por	3,052	3,073	9	A	MisL	3,222
137	0	4	*x*	*x*		38.5	*x*	McClosky	MisL	L	Por	3,012	3,068	6	D	MisL	3,120
138	0	1	*x*	*x*		37.8	0.18	Aux Vases	MisU	S	Por	1,942	1,969	5	D	MisU	1,969
139	2	45													A	MisL	3,058
140	0	4	*x*	*x*		38.0	*x*	Pennsylvanian	Pen	S	Por	1,719	1,728	11			
141	2	39	*x*	*x*		38.0	*x*	Cypress	MisU	S	Por	2,444	2,480	15			
142	0	2	*x*	*x*		34.8	*x*	McClosky	MisL	L	Por	2,793	2,881	13			
143	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	2,703	2,714	6	D	MisL	2,714
144	0	120													A	MisL	2,880
145	0	3	*x*	*x*		*x*	*x*	Palestine	MisU	S	Por	1,819	1,835	16			
146	0	117	*x*	*x*		38.6	0.29	Cypress	MisU	S	Por	2,433	2,454	17			
147	0	2	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	2,793	2,881	15	D	MisL	2,556
148	0	95	*x*	*x*		37.4	0.19	Bethel	MisU	S	Por	1,259	1,285	17	A	MisL	1,550
149	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	1,359	1,370	11	D?	MisU	1,370
150	11	30	*x*	*x*		42.0	*x*	McClosky	MisL	L	Por	3,385	3,412	11	A	MisL	3,523
151	1	24	*x*	50		40.2	0.14	McClosky	MisL	L	Por	3,236	3,277	10	A	MisL	3,384
152	2	44													A	MisL	3,273
153	1	2	*x*	*x*		38.5	*x*	Aux Vases	MisU	S	Por	2,982	3,029	13			
154	0	1	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	3,010	3,160	*y*			
155	1	43	*x*	75		38.5	*x*	McClosky	MisL	L	Por	3,121	3,178	9			
156	4	46													A	MisL	3,160
157	0	1	*x*	*x*		*x*	*x*	Aux Vases	MisU	S	Por	2,929	2,957	16			
158	4	45	*x*	100		*x*	*x*	McClosky	MisL	L	Por	3,049	3,114	12			
159	0	3	*x*	*x*		*x*	*x*	McClosky✓	MisL	L	Por	3,377	3,399	7	D	Devonian	5,645
160	0	9	*x*	*x*		34.4	0.18	McClosky	MisL	L	Por	3,413	3,453	11	D	MisL	3,485
161	0	1	*x*	*x*		38.5	*x*	McClosky	MisL	L	Por	3,080	3,092	*y*	D	MisL	3,135
162	20	40	*x*	40		40.0	*x*	McClosky	MisL	L	Por	3,321	3,341	12	A	MisL	3,502
163	0	0	*x*	*x*		38.5	*x*	McClosky	MisL	L	Por	3,144	3,154	5	D	MisL	3,154
164	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,129	3,206	11	D	MisL	3,206
165	2	3	*x*	*x*		40.0	*x*	McClosky	MisL	L	Por	3,287	3,337	7	D	MisL	3,460
166	0	2													D	MisL	3,201
167	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,711	2,721	9			
168	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,191	3,201	*y*			
169	1	21													A	MisL	3,520
170	1	12	*x*	*x*		39.8	0.14	Aux Vases	MisU	S	Por	3,221	3,290	10			
171	0	9	*x*	*x*		38.0	0.16	McClosky	MisL	L	Por	3,316	3,391	14			
172	0	11													A?	MisU	3,074
173	0	10	*x*	820		39.6	*x*	Waltersburg	MisU	S	Por	2,147	2,268	17			
174	0	1	*x*	*x*		38.9	*x*	McClosky	MisL	L	Por	2,998	3,017	10			
175	0	2													A	MisL	3,025
176	0	1	*x*	*x*		39.4	*x*	Aux Vases	MisU	S	Por	2,942	2,964				
177	0	1	*x*	*x*		37.6	*x*	McClosky	MisL	L	Por	2,955	2,961	10			
178	0	7	*x*	50		*x*	*x*	McClosky	MisL	L	Por	3,077	3,124	12	A	MisL	3,150
179	14	0	*x*	*x*		*x*	*x*	Waltersburg	MisU	S	Por	2,235	2,272	18	A	MisU	3,089
180	701	4,278															
181	704	17,490															

Of the 478 wildcat wells 30 were successful in discovering oil or gas in commercial quantities, either new fields or extensions of old fields. The results of an investigation to ascertain the reason for the locations of as many as possible of the wildcat wells are set forth in the following table:

Reason for Drilling	Total Number	Successful	Per Cent
Geology and geophysics	173	24	14
Geochemical	1	0	0
Not based on geologic or geophysical information	239	6	3
Unknown	65	0	0
Total	478	30	6

Economic Data

On the basis of posted prices, the total value of the oil produced in 1939 was approximately $94,835,500. The average price calculated from the available data on production and prices for the state was slightly more than $1.00 per barrel. This does not take into consideration the fact that some oil was sold under the posted price. If data on the amount and price of this oil were available, they would make both the total value and the average price somewhat lower than mentioned above. Posted prices for Illinois crude oil in 1939 were as follows:

Beginning Date	Oct. 13, 1938	June 8, 1939	Aug. 16, 1939	Sept. 13, 1939
Old fields	$1.05	$0.95	$0.95	$0.95
Central basin fields	1.15	1.05	1.05	1.05
Salem	1.15	1.05	0.85	0.95

Beginning Date	Oct. 10, 1939	Oct. 21, 1939	Dec. 31, 1939
Old fields	$0.95	$0.95	$0.95
Central basin fields	1.05	1.05	1.05
Salem	0.95	1.05	1.05
Griffin: sandstone production	0.95	0.95	0.95
McClosky "sand" production	0.85	0.85	0.85

In 1939 a total of 7,521,986 ft. of hole was drilled in the state. Of this amount 6,079,423 ft. was drilled in producing wells. If an average cost of $3.00 per foot is assumed, it is calculated that the total investment in drilling was $22,565,958, including both producing wells and dry holes. The average depth of all wells drilled in the state in 1939 was 2025 ft.

and the average initial daily production of the oil wells was 378 bbl. (For details see Tables 2 and 3.)

Pipe Lines and Refineries

There was much pipe-line construction in Illinois in 1939 (Fig. 2); 441 miles of 10-in. line was laid for transporting crude oil, and 255 miles of 8-in. line for transporting gasoline. The Texas-Empire Pipe Line Co. constructed a 10-in. line from the Salem field in Marion County to Heyworth, Ill., where it joins the main line, a distance of approximately 223 miles. The capacity of the line was 40,000 bbl. daily but plans are now under way to construct 42 miles of 10-in. loop between the Salem field and the Heyworth station and 38 miles of 12-in. loop on the trunk line from the Heyworth station to the Wilmington station. These additional loops will increase the capacity of the Salem-Heyworth line from 40,000 to 65,000 bbl. per day estimated and of the trunk line from Heyworth to Wilmington from 80,000 to 95,000 bbl. per day estimated.

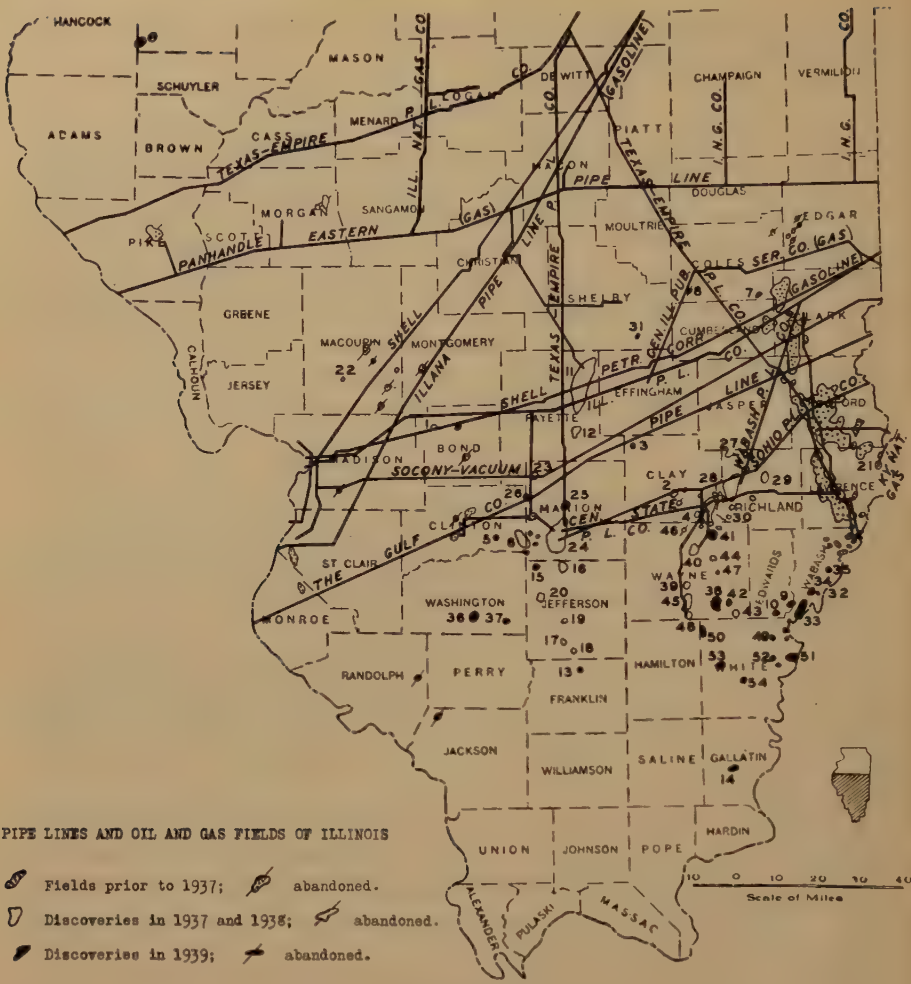
Socony-Vacuum constructed a 10-in. line from its Mitchell station between East St. Louis and Wood River, Ill., through Illinois and Indiana to Lima, Ohio. Approximately 147 miles of the line is in Illinois. Its daily capacity is reported to be 40,000 barrels.

Sohio Pipe Line Co. constructed 71 miles of 10-in. line from the Salem field to its station at Stoy, Ill., in the old Crawford County field. The line from Stoy, Ill., to Olean, N. Y., was formerly owned by the Tide Water Associated Oil Co. but recently was purchased by the Sohio Pipe Line Company.

The Illana Pipe Line Co. constructed 255 miles of 8-in. gasoline line in Illinois from East St. Louis, Ill., to East Chicago, Ind. This line connects with the Phillips Petroleum Company's gasoline line from Borger, Texas, at the East St. Louis terminal. A 500,000-bbl. storage capacity has been provided at East Chicago.

In addition to construction of trunk lines in the state, other lines were "looped" in order to increase their capacity and short lines from the fields to pumping stations and railroad loading racks were constructed.

A number of small refineries were constructed at various points in the Illinois basin as a result of the increased production. Their location close to producing areas gives them the advantage of obtaining crude oil at low prices and furnishes an outlet for production from many independent operators. At the end of the year, 29 refineries were operating in the state with a total daily capacity of 193,350 bbl. Of the total number of refineries, 17 have a daily capacity of 2000 bbl. or less. Ten refineries have both skimming and cracking units. Crude oil produced in Illinois fields is marketed mainly in the refineries of the Central Refining district (refineries in Illinois, Indiana, Kentucky, Michigan and Ohio). For December 1939 the runs to stills in this district were 17,848,000 bbl. Of



PIPE LINES AND OIL AND GAS FIELDS OF ILLINOIS

▨ Fields prior to 1937; ▨ abandoned.

▯ Discoveries in 1937 and 1938; ▯ abandoned.

■ Discoveries in 1939; ■ abandoned.

NEW FIELDS

1. Bond: Sorento
2. Clay: Flora
3. Iola*
4. Clay, Wayne: Clay City
5. Clinton: Hoffman*
6. Clinton, Marion: Centralia
7. Coles: Hutton*
8. Mattoon*
9. Edwards: Cowling*
10. Edwards, White: Grayville*
11. Fayette: Louden-Beecher City
12. St. James
13. Franklin: Whittington*
14. Gallatin: Junction*
15. Jefferson: Cravat*
16. Dix
17. Elk Prairie
18. Ina
19. Marcoe
20. Roaches
21. Lawrence: Russellville gas
22. Macoupin: Plainview gas
23. Marion: Patoka
24. Salem-Lake Centralia
25. Tonti*
26. Marion, Clinton: Fairman*
27. Richland: Dundas*
28. Noble
29. Olney
30. Schnell
31. Shelby: Stewardson*
32. Wabash: East Keensburg*
33. Griffin*
34. Keensburg*
35. Mt. Carmel*

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* Discoveries and extensions in 1939.

36. Washington: Cordes*
37. Dubois*
38. Wayne: Barn Hill*
39. Boyleston
40. Cisne
41. Enterprise*
42. Goldengate*
43. Leech Twp.
44. Mt. Erie
45. North Aden
46. Rinard
47. South Mt. Erie*
48. Wayne, Hamilton: Aden
49. White: Calvin*
50. Mill Shoals*
51. New Harmony*
52. Phillipstown*
53. Stokes*
54. Storms*

JANUARY 1, 1940

ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 2.—PIPE LINES AND OIL AND GAS FIELDS OF ILLINOIS.

this amount Illinois production was 60.1 per cent as compared to 30.9 per cent for January 1939. Stocks of crude petroleum on hand in Illinois Dec. 31, 1939, were 12,983,000 bbl. as compared with 11,752,000 bbl. on Dec. 31, 1938. Stocks of refined products in the Central Refining district compared with the previous year are as follows:

	Dec. 31, 1939	Dec. 31, 1938
Gasoline	13,621,000	12,119,000
Gas oil and distillate fuel	3,681,000	3,427,000
Residual fuel oil	2,964,000	4,025,000

EXPLORATION METHODS

Subsurface geology and geophysics, largely the reflection seismograph, are still the principal methods used in guiding exploration and development. Soil analysis as a means of exploration was conducted in various areas in the state. Gravimeters and magnetometers are being used to a small extent and structure test drilling is carried on by a few companies.

Development in 1939 was largely in the Salem and Louden fields and in White and Wabash Counties where a number of new fields in the younger productive formations were discovered (Table 4). December 1939 marked the beginning of Devonian limestone development in the Salem field. The Kingwood Oil Co. and Bell-Shanafelt No. 18A, NE¼ NW¼ NE¼ sec. 20, T. 2 N., R. 2 E., was the discovery well in this formation in the Salem field (Table 5). The well reached the top of the Devonian limestone at a depth of 3345 ft. The initial production was 3024 bbl. In the Salem field the producing zone is porous dolomite consisting of an average of 30 ft. of pay, which is encountered 50 to 55 ft. below the top of the limestone. Many wells record as much as 20 ft. of poor saturation overlying 20 ft. of good saturation. The average initial production from the first wells was approximately 3300 bbl. No water was produced with the oil.

There was considerable development of the Devonian limestone in the Sandoval pool in central western Marion County, where the Bethel sandstone (Benoist sand) has produced for many years. The discovery well in the Devonian limestone was drilled in December 1938 and the development of this formation in the field was carried on throughout the year. By the end of the year 22 wells had been completed in the field with an average initial production of 1450 bbl. A considerable quantity of water is produced with the oil in the field; a well drilled near the southern limit of the producing area had an initial production of 600 bbl. of oil and 1400 bbl. of water. To the end of 1939 the Devonian limestone in the field had produced approximately 794,000 bbl. of oil.

In December 1939, wells were drilled to the Devonian limestone in the Centralia and Bartelso fields in Clinton County and both were producers (Table 5).

These recent Devonian limestone discoveries will be followed by the drilling of many Devonian wells in these fields and will encourage deeper

TABLE 2.—*Summary of Drilling and Initial Production in Illinois for 1939*

County	Number of Wells Drilled in 1939			Total Initial Production		Footage Drilled in 1939	
	Total Completed	Total Producing		Oil, Bbl.	Gas, Millions Cu. Ft.	Total	Producing Wells
		Oil	Gas				
Adams	2	0	0	0	0	1,853	0
Bond	7	0	0	0	0	14,929	0
Brown	4	0	0	0	0	2,406	0
Champaign	2	0	0	0	0	2,900	0
Christian	4	0	0	0	0	4,850	0
Clark	20	4	0	150	0	21,883	5,351
Clay	159	136	0	66,725	0	484,954	422,153
Clinton	62	35	0	3,135	0	81,105	46,733
Coles	17	3	0	33	0	27,286	3,301
Cook	1	0	0	0	0	210	0
Crawford	7	2	0	12	0	11,901	2,562
Cumberland	11	0	0	0	0	19,914	0
Douglas	2	0	0	0	0	928	0
Edgar	9	0	0	0	0	9,900	0
Edwards	34	17	0	2,443	0	98,946	48,189
Effingham	13	0	0	0	0	34,521	0
Fayette	960	895	0	236,037	0	1,506,441	1,395,934
Franklin	9	1	0	199	0	31,251	3,068
Fulton	3	0	0	0	0	2,099	0
Gallatin	19	6	0	319	0	39,344	9,025
Greene	2	0	0	0	0	1,730	0
Hamilton	7	1	0	72	0	27,707	3,381
Hancock	3	1	0	3	0	1,295	382
Henderson	1	0	0	0	0	1,235	0
Jackson	1	0	0	0	0	1,380	0
Jasper	8	1	0	10	0	18,117	722
Jefferson	73	36	0	4,963	0	167,136	73,640
Jersey	1	0	0	0	0	1,802	0
Johnson	1	0	0	0	0	1,747	0
Knox	1	0	0	0	0	800	0
Lawrence	41	3	18	68	159.4	55,639	23,676
Livingston	1	0	0	0	0	1,530	0
McDonough	7	1	0	1	0	3,946	512
Macon	2	0	0	0	0	5,300	0
Macoupin	4	0	3	0	0.7	2,904	1,364
Madison	9	1	0	25	0	11,720	1,300
Marion	1,242	1,155	0	667,813	0	2,449,707	2,277,051
Monroe	16	7	0	200	0	10,272	3,164
Montgomery	11	1	0	2	0	14,883	680
Morgan	1	0	0	0	0	1,160	0
Moultrie	4	0	0	0	0	8,872	0
Peoria	1	0	0	0	0	1,562	0
Perry	16	0	0	0	0	22,450	0
Pike	2	0	0	0	0	1,452	0
Randolph	7	0	0	0	0	9,546	0
Richland	102	91	0	26,697	0	279,741	246,240
St. Clair	38	21	0	1,403	0	36,939	12,817
Saline	7	0	0	0	0	17,835	0
Sangamon	2	0	0	0	0	4,633	0
Schuyler	3	0	0	0	0	2,655	0
Shelby	17	1	0	28	0	34,559	1,969
Tazewell	2	0	0	0	0	3,700	0
Wabash	217	170	0	28,733	0	537,130	418,576
Warren	1	0	0	0	0	1,050	0
Washington	133	96	0	7,660	0	181,702	123,297
Wayne	237	193	0	56,186	0	893,323	761,200
White	104	68	3	15,033	109.8	295,598	193,136
Williamson	5	0	0	0	0	11,608	0
	3,675	2,946	24	1,117,750	269.9	7,521,986	6,079,423

TABLE 3.—*Data on New Fields,*[1] *January* 1, 1940

County and Field	Producing Wells	Dry Holes[2]	Drilling Wells	Rigs Standing	Rigging Up	New Locations	Acres	Approximate Cumulative Production to Dec. 31, 1939		Approximate Production 1939		Total Initial Production	
								Oil, Bbl.	Gas. Millions Cu. Ft.	Oil, Bbl.	Gas, Millions Cu. Ft.	Oil, Bbl.	Gas, Millions Cu. Ft.
Bond: Sorento	1	0	0	2	0	1	10	y	0	y	0	0	0
Clay: Flora	17	6	0	0	0	1	290	214,000	0	147,000	0	424	0
Iola	2	3	0	0	0	0	20	y	0	y	0	42	0
Clay, Wayne: Clay City	375	18	2	8	0	0	7,930	11,895,000	0	6,336,000	0	72,157	0
Clinton: Hoffman	1	0	0	0	0	0	10	y	0	y	0	42	0
Clinton, Marion:													
Centralia	539	44	5	2	7	0	2,190	5,922,000	0	2,895,000		2,145	0
Edwards: Cowling	11	1	0	2	1	0	100	25,000	0	25,000	0	1,429	0
Edwards, White:													
Grayville	8	0	0	0	3	1	70	30,000	0	30,000	0	1,111	0
Fayette:													
Louden-Beecher City	1,331	74	5	39	4	5	16,370	20,237,000	0	18,345,000	0	229,514	0
St. James	76	4	2	8	2	2	1,030	494,000	0	445,000	0	7,523	0
Franklin: Whittington	1	0	0	0	0	0	10	y	0	y	0	199	0
Gallatin: Junction	6	0	0	2	0	0	60	y	0	y	0	319	0
Jefferson: Cravat	6	0	0	4	0	0	100	14,000	0	14,000	0	501	0
Dix	57	0	0	0	0	0	1,250	y	0	y	0	3,528	0
Elk Prairie[3]	1	0	0	0	0	0	10	y	0	y	0	0	0
Ina	1	2	0	0	0	0	10	y	0	y	0	0	0
Marcoe	1	3	0	0	0	0	10	y	0	y	0	18	0
Roaches	9	3	1	1	0	0	110	70,000	0	70,000	0	916	0
Lawrence:													
Russellville gas	32	6	0	1	0	0	1,020	0	1,065.1	0	963.7	0	159.5
Marion: Patoka	104	20	0	1	0	0	720	1,661,000	0	494,000	0	0	0
Salem-Lake Centralia	1,577	57	19	55	18	10	8,870	52,619,000	0	49,724,000	0	627,187	0
Tonti	35	8	0	1	0	0	270	910,000	0	910,000	0	12,433	0
Marion, Clinton:													
Fairman	11	1	0	6	0	0	160	y	0	y	0	1,331	0
Richland: Dundas	18	0	4	5	0	1	400	y	0	y	0	16,971	0
Noble	212	33	0	2	0	0	3,540	6,852,000	0	1,674,000	0	9,104	0
Olney	36	11	0	0	0	0	510	753,000	0	338,000	0	622	0

TABLE 3.—(*Continued*)

County and Field	Producing Wells	Dry Holes[2]	Drilling Wells	Rigs Standing	Rigging Up	New Locations	Acres	Approximate Cumulative Production to Dec. 31, 1939		Approximate Production 1939		Total Initial Production	
								Oil, Bbl.	Gas, Millions Cu. Ft.	Oil, Bbl.	Gas, Millions Cu. Ft.	Oil, Bbl.	Gas, Millions Cu. Ft.
Schnell	4	5	0	0	0	0	40	y	0	y	0	0	0
Shelby: Stewardson	1	0	0	0	0	0	10	y	0	y	0	28	0
Wabash: Griffin	47	14	2	7	2	2	690	169,000	0	169,000	0	6,263	0
East Keensburg	1	0	0	1	0	0	10	y	0	y	0	287	0
Keensburg	120	12	3	8	4	0	700	783,000	0	783,000	0	22,133	0
Mt. Carmel	2	0	0	1	0	0	20	y	0	y	0	50	0
Washington: Cordes	95	6	0	3	2	0	1,090	468,000	0	468,000	0	7,414	0
Dubois	1	1	1	0	0	0	10	y	0	y	0	46	0
Wayne: Barn Hill	41	5	0	1	4	0	750	593,000	0	593,000	0	16,664	0
Boyleston	25	4	0	0	2	1	450	218,000	0	218,000	0	7,523	0
Cisne	47	0	0	1	1	0	960	y	0	y	0	4,874	0
Enterprise	50	3	0	2	2	0	1,450	1,269,000	0	1,269,000	0	17,894	0
Goldengate	3	0	0	0	0	0	30	y	0	y	0	542	0
Leech Twp	9	1	2	1	0	0	240	105,000	0	96,000	0	970	0
Mt. Erie	1	0	0	0	0	0	10	y	0	y	0	0	0
North Aden	60	9	0	1	0	0	1,230	1,030,000	0	725,000	0	1,791	0
South Mt. Erie	1	0	0	0	0	0	10	y	0	y	0	30	0
Wayne, Hamilton: Aden	5	2	0	1	0	0	200	y	0	y	0	72	0
White: Calvin	2	1	0	0	0	0	20	y	0	y	0	265	0
Mill Shoals	22	1	5	5	3	0	400	127,000	0	127,000	0	4,499	0
New Harmony	11	0	2	1	0	0	130	y	0	y	0	2,270	0
Phillipstown	2	0	1	1	1	0	20	y	0	y	0	305	0
Stokes	7	1	2	1	0	0	140	y	0	y	0	2,011	0
Storms	17[4]	2	1	23	3	3	540	60,000	0	60,000	0	5,581	109.8[6]
Total	5,042	361	57	197	59	27	54,220[5]	113,548,000	1,065.1	90,299,000	963.7	1,089,028	269.3

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[1] Fields discovered since Jan. 1, 1937, with the exception of the following, which have been abandoned: Mattoon, Coles County; Rinard, Wayne County.

[2] Within ¼ mile of production.

[3] Inactive.

[4] Three gas wells.

[5] Includes 1050 acres natural gas production; 1020 acres Russellville gas field; 30 acres Storms field.

[6] Gas not marketed.

y Not available for publication.

TABLE 4.—*Discovery Wells of New Fields and Extensions in Illinois for* 1939

Field	County	Company and Farm	Location	Total Depth, Ft.	Producing formation		Initial Production, Bbl.	Date of Discovery	Number of Wells in Pool 1-3-40
					Depth to Top, Ft.	Name			
Barnhill	Wayne	Carl Robinson, Felix No. 1	SW SE SE 27-2S-8E	3,409	3,386	McClosky "sand"	460	2-7-39	41
Calvin	White	J. W. Carter et al., Johnson No. 1	SW NE NE 12-4S-10E	3,201	3,191	McClosky "sand"	210	10-10-39	2
Clay City	Wayne	Wiser Oil, Shannon No. 1A[1]	C W NE SW 25-2N-8E	3,132	3,048	McClosky "sand"	190	12-12-39	1
Cordes	Washington	G. H. Blankenship, Dennis No. 1	NE SW NE 14-3S-3W	1,239	1,228	Bethel sandstone	25	2-7-39	95
Cowling	Edwards	C. C. McFadden, Bump No. 1	C SE SW 34-2S-14W	2,643	2,625	Cypress sandstone	240	10-10-39	11
Cravat	Jefferson	Vawder, Kell No. 1	NW SW NE 9-1S-1E	2,084	2,065	Bethel sandstone	72	8-8-39	6
Dubois	Washington	Shell, Dix No. 1	C NW NE NE 19-3S-1W	1,370	1,359	Bethel sandstone	46	11-28-39	1
Dundas	Richland	Pure, Coen No. 1	SE SE SE 36-5N-9E	2,930	2,830	McClosky "sand"	1,458	9-6-39	18
E. Keensburg	Wabash	Marvel Oil, Beall No. 1	C NE NW 11-2S-13W	2,714	2,703	McClosky "sand"	287	12-12-39	1
Enterprise	Wayne	Witcher Drill., Fitch No. 1	C N SE SE 3-1N-8E	3,100	3,087	McClosky "sand"	194	4-18-39	50
Fairman	Marion	Shell, Lutz No. 1	NW NW SE 18-3N-1E	1,439	1,429	Bethel sandstone	107	11-7-39	11
Goldengate	Wayne	New Penn Dev., Wagner No. 1	NW SW NE 30-2S-9E	3,441	3,432	McClosky "sand"	20	3-7-39	3
Grayville	Edwards	Kingwood, Johnson No. 1	SE SE NE 18-3S-11E	3,269	3,096	McClosky "sand"	415	9-6-39	8
Griffin	Wabash	W. N. Bartlett, Stansfield No. 1	SW SE SE 19-2S-13W	1,719	1,713	Pennsylvanian sandstone	210	6-13-39	47
Hoffman	Clinton	Bell Oil, H. Knolhoff No. 1	NE SE SW 2-1N-2W	1,329	1,324	Bethel sandstone	42	12-30-39	1
Hutton	Coles	W. R. Miller, Giffin No. 1	SE NE NE 22-11N-10E	538	523	Pennsylvanian sandstone	10	4-25-39	2[4]
Iola	Clay	Duncan, Liggett No. 1	SE NW SE 17-5N-5E	2,383	2,356	Aux Vases sandstone	42	5-2-39	2
Junction	Gallatin	Coates et al., Greene No. 2	SE SE SE 17-9S-9E	1,794	1,757	Waltersburg sandstone	130	5-16-39	6
Keensburg	Wabash	Neff, Bump No. 1	NW NE NW 9-2S-13W	2,424	2,397	Cypress sandstone	286	7-25-39	120
Mt. Carmel	Wabash	Washburn, Pfeifer No. 1	SW SW SW 13-1S-13W	1,955	1,940	Tar Springs sandstone	44	6-27-39	2
Mattoon	Coles	Wheeles & Whisenant, Micheal No. 1	SW SW NW 1-11N-7E	1,919	1,835	Cypress sandstone	18	2-21-39	[4]
Mill Shoals	White	Nation et al., McIntosh No. 1	C SE SW 31-3S-8E	3,405	3,360	McClosky "sand"	76	7-11-39	22
New Harmony	White	Sun Oil, Ford No. 1[1]	NW NE NE 18-5S-14W	3,017	2,998	McClosky "sand"	20	7-11-39	11
Phillipstown	White	Sun Oil, Garner No. 1	SW SE SW 1-5S-10E	2,964	2,942	Aux Vases sandstone	20	10-24-39	3
S. Mt. Erie	Wayne	Cayuna Oil, Brough No. 1	C E SW NE 23-1S-8E	3,206	3,129	McClosky "sand"	30	12-5-39	1
Stewardson	Shelby	J. A. Aylward, Wabash RR Right of Way No. 1	C N/2 N/2 27-10N-5E	1,969	1,942	Aux Vases sandstone	28	4-18-39	1
Stokes	White	Penn-Ill. O. & G., Pyle No. 1	E SE NE 12-6S-8E	3,132	3,082	McClosky "sand"	423	10-3-39	7
Storms	White	Eason Oil, Storms Heirs No. 1	C W SE SW 14-6S-9E	2,992	2,215	Waltersburg sandstone	12.3[3]	7-11-39	[2]
Tonti	Marion	Harvey et al., Mercantile Bank No. 1	NE SE 33-3N-2E	2,193	2,160	McClosky "sand"	157	5-2-39	35
Whittington	Franklin	Gulf Ref., Hinman No. 1	SE SW NE 19-5S-3E	3,068	2,869	McClosky "sand" and St. Louis limestone	199	7-5-39	1

[1] Extension.
[2] 14 oil, 3 gas.
[3] Million cubic feet of gas.
[4] Abandoned.

exploration in both new and old fields where production is obtained from younger formations and where the deeper formations have not been tested. During the past year, 190 wells were drilled to the Devonian or deeper in the state. Of this number 61 wells were drilled in producing fields; the remainder were "wildcat" wells.

TABLE 5.—*Discovery Wells in Deeper Formations in Areas of Previous Production*

Field	County	Company and Farm	Location	Total Depth, Ft.	Producing formation		Initial Production, Bbl.	Discovery Date	Number of Wells 1-3-40
					Depth to Top, Ft.	Name			
Bartelso........	Clinton	Paul Mosebach, Robbin No. 1	SE SW SE 5-1N-3W	2,431	2,416	Devonian limestone	162	12-5-39	1
Centralia........	Clinton and Marion	Lilly, Gum No. 1	SW SE NE 13-1N-1W	2,933	2,884	Devonian limestone	782	12-31-39	1
Salem...........	Marion	Magnolia, W. B. Young No. 24	NW SW NW 20-2N-2E	2,230	2,204	Salem limestone	288	11-28-39	5
Salem...........	Marion	Kingwood, Bell, Shanafelt No. 18A	NE NW NE 20-2N-2E	3,502	3,345	Devonian limestone	3,024	11-21-39	7

NATURAL GAS

Gas was marketed from two fields in Illinois during 1939, the Russellville field in Lawrence County and the Ayers field in Bond County. The Russellville gas field, in northeastern Lawrence County, includes 920 productive acres and produced 963,712,000 cu. ft. during the year. The field was discovered in 1937 and had produced 1,065,112,000 cu. ft. of gas to the end of 1939. Production is obtained from the Buchanan sandstone of Pennsylvania age. The gas is "dry" and the average B.t.u. value is 950. The Ayers gas field in north central Bond County includes 325 productive acres and produced 13,626,000 cu. ft. during 1939. The field was discovered in 1922 and had produced 180,626,000 cu. ft. of gas to the end of 1939. Production is obtained from Aux Vases sandstone of the Chester series. The gas is "dry" and the B.t.u. value is 1050.

In July 1939 the Eason Oil Company's Storms Heirs No. 1 well was drilled in sec. 14, T. 6 S., R. 9 E., White County, and was completed as a gas well in the Waltersburg sandstone of the Chester series at a depth of 2215 ft. The well had an initial production of 12,300,000 cu. ft. of gas. Other wells drilled later produced both gas and oil. On March 5 five wells were producing gas and 30 wells producing gas and oil in the Storms field. The initial gas production of all the wells in the field

TABLE 6.—*Illinois Completions and Production since January* 1, 1936

Date	Completions	Producing Wells	Production (Thousands of Barrels)		
			New Fields	Old Fields	Total[2]
1936	92	52			4,445
1937	449	292	2,884	4,542	7,426
1938	2,541	2,010	19,811	4,264	24,075
1939					
January	240	208	4,194	252	4,446
February	241	200	4,300	242	4,542
March	282	205	5,116	264	5,380
April	210	167	5,157	258	5,415
May	316	263	6,575	274	6,849
June	386	311	6,819	264	7,083
July	273	221	8,457	280	8,737
August	377	310	9,569	283	9,852
September	320	244	10,172	271	10,443
October	319	266	10,322	279	10,601
November	363	286	9,955	267	10,222
December	348	289	10,465	267	10,732
	3,675	2,970	91,101[1]	3,201	94,302

[1] Includes new Devonian production from old fields.

[2] U. S. Bureau of Mines monthly petroleum statements.

was from 4 to 30 million cu. ft. of gas. When the oil wells were drilled the gas was then released and burned in flares. It has been reported that approximately 100,000,000 cu. ft. of gas is being burned daily in this field. A small amount is used in drilling and pumping operations, and in heat-treatment of the oil produced from the field. The gas is "dry" and the heat value is 930 B.t.u. per cubic foot.

A considerable quantity of gas is being produced with the oil in the Salem field, in southwestern Marion County. The field, which is almost two years old, had produced approximately 75,000,000 bbl. of oil to the end of March 1940. Oil is produced from the Bethel and Aux Vases sandstones of the Chester series, the McClosky "sand" and the Salem limestone of Lower Mississippian age, and the Devonian limestone. Natural gas is produced with the oil from each producing formation. A comparison of the estimated total amount of gas produced by each up to the end of February 1940 is as follows: Bethel sandstone, 35 per cent; Aux Vases sandstone, 9; Salem limestone, 1; McClosky "sand," 30; Devonian limestone, 25.

A recent estimate of the amount of gas produced in the Salem field is 250,000,000 cu. ft. daily. It is also estimated that approximately half of the ultimate gas production has been produced from the formations now producing oil. A small amount of the gas is used for repressuring, drilling, and heating purposes, the remainder is burned in flares. The gas is "wet" and the average B.t.u. value is approximately 1600 per cubic foot. There is an average yield of from 1 to 1¼ gal. of natural gasoline from 1000 cu. ft. of gas.

In the Louden field, in northeastern Fayette County, natural gas is likewise produced with the oil. The Louden field is more than two years old, and to the end of March 1940 had produced approximately 26,500,000 bbl. of oil. Production is obtained from the Cypress, Paint Creek Stray, and Bethel sandstones of the Chester series. Natural gas is produced throughout the pool; however, there is a "gas cap" in the north part centering from sec. 28, T. 8 N., R. 3 E., northeast to sec. 15, T. 8 N., R. 3 E. There is an average yield of from 1.3 to 1.5 gal. of natural gasoline from 1000 cu. ft. of natural gas from the field.

It is estimated that approximately 30,000,000 cu. ft. of gas is produced daily in the field. Of this amount 1,000,000 cu. ft. is used for repressuring, and it is estimated that 3,000,000 cu. ft. is used for lease operations, 3,500,000 for fuel, and the remaining 22,500,000 cu. ft. is burned in flares.

In other new fields in the state a small amount of natural gas is produced with the oil. The amount of gas now produced is very small in the first McClosky "sand" fields in the central basin area as compared to the production when the fields were first developed. Although there has been an increase in the gas-oil ratio in these fields, oil production has declined to such a low figure that the natural gas production is insignificant. The estimated average gas-oil ratio for many of these fields is 1000 cu. ft. of gas per barrel of oil. Part of the gas is used on the leases for pumping and heating purposes, the remainder is burned in flares.

During the latter part of the year 1938 and early in 1939, five shallow gas wells were completed in Hillyard township, T. 8 N., R. 8 W., near Plainview, Macoupin County. The wells were completed in the basal Pennsylvanian sandstone at an average depth of 440 ft. The initial production ranged from 125,000 to 750,000 cu. ft. per day. The gas is "dry" and has an average calculated B.t.u. value of 806 per cubic foot. The gas has not yet been marketed. There are three abandoned gas fields in Macoupin County—Spanish Needle Creek, Gillespie-Benld, and Staunton (Table 1). These had a total productive area of 560 acres and during the life of the fields they produced a total of 1,200,000,000 cu. ft. of gas. The gas was marketed in near-by cities within the county. The last field was abandoned in 1935.

Improved Recovery Methods

Repressuring.—A repressuring project by the Texas Company in the Salem field was continued in 1939. At the end of the year approximately one million cubic feet of gas daily was being injected into 11 gas-input wells. Three new input wells were added during the year. No data as to the results in increased recovery are available as yet.

In the northern part of the Louden field the Carter Oil Co. has 39 gas-input wells in T. 8 N., R. 3 E., Fayette County. Of this total, 5 input wells were completed in 1938 and on Jan. 1, 1939 an accumulated volume of 2,636,000 cu. ft. of residue gas was returned to the reservoir through these wells. On Jan. 1, 1940, the accumulated injection volume to all sands was estimated to be 92,000,000 cu. ft. This project is in an early stage and is not intended to increase actual measured daily production at present.

Water-flooding.—In the Clay City field, which is producing from the McClosky sand, the Pure Oil Co. started an experimental water-flooding project on the B. Travis lease, sec. 33, T. 3 N., R. 8 E., Clay County. Water was first injected in the B. Travis No. 1 well on Sept. 28, 1939, at an initial rate of about 1300 bbl. per day, and on Jan. 1, 1940, an estimated 100,000 bbl. had been used. As the project has been in operation for only a short time, no data on its results could be obtained.

During 1939 there was little change in repressuring or water-flooding operations in the old southeastern Illinois field or in the old fields of western and southwestern Illinois. The fact that production was curtailed approximately one-third throughout the year was unfavorable to the initiation of new projects or to the expansion of old ones.

LEGISLATION

Two new statutes affecting the oil and gas industry were enacted by the State of Illinois in 1939. These are House Bill No. 1079, approved July 11, 1939, "An Act to require the reporting of information essential for the sealing of wells to prevent escape of oil, gas, salt or fresh water or other materials from one stratum to another through such wells" and House Bill No. 1080 filed without signature, July 21, 1939, "An Act to amend Sections 2, 3, 4, 5, and 6 of 'An Act in relation to sinking, filling and operating of wells for oil, gas, water or other purposes,' approved May 16, 1905, as amended." The new laws require that permits to drill be issued by the Department of Mines and Minerals, Springfield, before drilling is started. They provide for the filing of well logs with the State Geological Survey within 30 days of completion, for the saving of well cuttings for geologic study in wells designated by the Survey and for making cores available for study by the Survey. The method prescribed for plugging abandoned wells has been amended in accordance with modern practice. The plugging laws are administered by the Department of Mines and Minerals, Springfield.

Unlike most of the major oil-producing states, Illinois does not have any comprehensive law providing for the conservation of oil and gas. Although the greater number of the oil-producing operations are being carried on efficiently, the existence of wasteful practices in some areas must be recognized. The burning of large quantities of natural gas in flares, particularly in the Salem pool, represents a loss of reservoir energy, which if utilized by returning the gas to the oil sand would result in a substantially greater ultimate recovery of oil. The drilling of too many wells in a small area, as for example in parts of the Salem pool and on town lots in Centralia, is not only an economic loss but will also result in physical waste through the premature abandonment of wells.

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Oil and Gas Developments in Indiana during 1939

By R. E. Esarey* and G. F. Fix†

(New York Meeting, February 1940)

During 1939, Indiana experienced a great increase in prospecting and drilling for oil and gas. Major activity, as during the preceding year, was in the southwestern part of the state, the Indiana portion of the Eastern Interior Coal Basin. An increasing interest was evident during the year, however, in the entire state, chiefly in northern Indiana (on the south flanks of the Michigan Basin) and in the old Trenton field of east central Indiana. In the latter area several tests to deeper horizons in the Trenton and to the underlying St. Peter sandstone were completed. Results in this area have been discouraging, however, since these deeper horizons are very erratic. The regional structure in the Indiana portion of the Michigan Basin is generally favorable to oil accumulation, but the picture is complicated by a uniform mantle of glacial drift and a lack of subsurface information. Several wells were started during the last half of 1939 to test the Devonian and Trenton formations in this area. Production from these formations was found at several localities many years ago, but, no sustained effort has been made to locate pools in this area, which covers perhaps 20 counties.

There were 377 wells completed in Indiana during 1939, and 77 others were in various stages of drilling at the close of the year. Of the 377 completed, 255 were classed as field locations and 122 as wildcats. The field wells were divided as follows: 156 oil wells, 39 gas wells, and 60 dry holes; the wildcats: 98 dry holes, 19 oil wells and 5 gas wells (wildcat oil and gas wells include deeper production in oil fields and field extensions as well as new field discoveries). During the year 218 more wells were completed than during 1938.

Outstanding developments for 1939 include the discovery of several new oil and gas fields. In the Griffin field, which was discovered during the closing days of the previous year, 103 wells were drilled, including field extensions. Of these, 97 were productive oil wells. This field now covers more than 2000 acres of productive area and has not as yet been defined. There are five producing horizons in the field, including the Waltersburg, Tar Springs, Elwren, and Aux Vases sandstones of Chester age and the McClosky horizon of the Ste. Genevieve limestone. Produc-

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tion from more than one horizon is obtained by combination wells or by drilling twins. Initial production of wells in the field varies from 100 to 3000 bbl. a day. Most of the wells show very little gas, although some have been gauged up to one million cubic feet a day. Pipe-line connections for the field are inadequate at present, since the only lines completed

TABLE 1.—*Oil and Gas Production in Indiana*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Alford, *Pike*	1919	240	960	3*xx*,*xxx*	3,450
2	Blairsville, *Posey-Vanderburgh*	1933	350	0	363,*xxx*	34,587
3	Bristow, *Perry*	1929	180	120	59,*xxx*	1,627
4	Cannelburg, *Daviess*	1925	6*xx*	5*x*	*y*	3,850
5	Enterprise, *Spencer*	1939	80	0	*y*	*y*
6	Francisco, *Gibson*	1929	950	150	98,*xxx*	17,640
7	Greensburg, *Decatur*	1893		37,000	0	0
8	Griffin, *Gibson-Posey*	1938	2,500	0	709,000	709,000
9	Harmon, *Pike*	1928	20	6*xx*	0	0
10	Harrison Co., *Harrison*	1910	0	6,6*xx*	0	0
11	Heusler, *Posey*	1938	250	0	169,000	141,292
12	Hudsonville, *Daviess-Pike*	1929	0	1,0*xx*	0	0
13	Loogootee, *Martin-Daviess*	1900	3*xx*	1,9*xx*	0	0
14	Monroe City, *Knox*	1922	4*xx*	0	*y*	1,450
15	New Harmony, *Posey*	1939	300	0	54,*xxx*	54,*xxx*
16	Oakland City, *Pike*	1907	3,1*xx*	2*xx*	*y*	10,800
17	Oaktown, *Knox*	1930	40	1,000	56,*xxx*	3,700
18	Oatesville-Wheeling, *Gibson*	1919	1,9*xx*	0	*y*	102,000
19	Prairie Creek, *Vigo*	1937	600	0	340,*xxx*	180,000
20	Rock Hill-Grandview, *Spencer*	1928	160	0	53,*xxx*	5,562
21	Rockport, *Spencer*	1939	0	720	0	0
22	Shelburn-Graysville, *Sullivan*	1911	5,0*xx*	1,6*xx*	6,8*xx*,*xxx*	55,*xxx*
23	Siosi, *Sullivan-Vigo*	1926	750	0	2,7*xx*,*xxx*	140,*xxx*
24	Trenton, "*Many*"	1886	127,*xxx*	650,*xxx*	107,*xxx*,*xxx*	20,*xxx*
25	Tri Co.-Somerville, *Pike-Gibson*	1925	350	80	150,*xxx*	7,740
26	Troy-Tell City, *Perry-Spencer*	1928	850	80	90,*xxx*	15,257
27	Union-Bowman, *Pike-Gibson*	1916	4,6*xx*	5*xx*	*y*	171,700
28	Unionville, *Monroe*	1929	0	1,4*xx*	0	0
29	Vanderburgh, *Vanderburgh*	1931	580	0	365,*xxx*	37,369
30	Veale, *Daviess*	1926	400	0	*y*	9,890
31	West Princeton, *Gibson*	1903	1,6*xx*	5*xx*	1,3*xx*,*xxx*	3,650
32	Total					1,729,564

[b] Footnotes to column heads and explanation of symbols are given on page 239.

at the end of the year were to river and railway terminals. The total cumulative initial production for wells drilled during 1939 is approximately 25,000 bbl. a day.

The Superior Oil Co. (California) opened a new field on Ribeyre Island, the New Harmony, along the Wabash in western Posey County in the early summer of 1939. The discovery well flowed 252 bbl. a day

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-Production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	
				During 1939		End of 1939			Number of Wells					
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
1	*y*	70	96	4	4	0	7	21	0	7	*y*	35	38	
2	0	0	34	5	0	0	30	0	0	30			29	
3	0	0	45	1	3	0	2*x*	0	0	2*x*			33	0.8
4	*y*	0	57	1	1	0	13	0	0	13			*y*	
5	0	0	3	3	0	3	0	0	0	3			*y*	
6	1238.7	8	38	3	0	1	22	3	0	22	690	*y*	26	
7	3,9*xx*	177.52	37*x*	5	5	0	0	21*x*	0	0	275	90		
8	0	0	90	89	0	0	90	0	*y*	8*x*			39	
9	*y*	15	28	0	3	0	0	4	0	0	450	25		
10	3,5*xx*	190.66	115	2	1	0	0	36	0	0	175	48		
11	0	0	22	13	1	0	21	0	0	21			37	
12	*y*	35.0	51	0	4	1	0	12	0	0	275	*y*		
13	*y*	8.5	58	0	0	1	0	6	0	0	250	75		
14	0	0	15	0	0	0	7	0	0	7			*y*	
15	0	0	19	19	0	0	19	0	0	19			39	
16	0	0	263	0	4	1	21	0	0	21			28	
17	1687.14	92.54	78	0	0	1	9	36	0	9	281	134	35	
18	0	0	253	0	0	0	185	0	0	185			32	
19	0	0	18	4	0	0	18	0	0	18			40	
20	0	0	17	1	0	0	10	0	0	10			38	
21	0	0	13	13	0	13	0	0	0	0	390	390		
22	1,*xxx*	32.976	1,093	0	0	0	342	14	0	342	110	30	35	
23		0	83	0	4	0	58	0	0	58			46	
24	80*x*,*xxx*	2*xx*	26,5*xx*	11	44	*y*	2*xx*	5*xx*	0	2*xx*	325	*y*	36	
25	*y*	*y*	74	0	0	0	13	*y*	0	13	*y*	*y*	34	
26	382.*x*	26.39	74	5	3	0	30	8	0	30	218	34	27–34	0.8
27	*y*	15	399	1	4	4	227	3	0	227	*y*	*y*	33	
28	0	0	17	0	0	0	0	0	0	0	250	*y*		
29	0	0	90	2	0	0	56	0	0	56			29	
30	0	0	73	0	0	0	27	0	0	27			*y*	
31	0	0	150	1	0	13	37	0	0	37			35	
32		871.586												

natural and during the year 19 other oil wells and one dry hole were drilled in this field, on the Indiana side. Several other wells were drilled in Illinois. Ribeyre Island is a cut-off island, caused by the Wabash River cutting across a meander, covering several square miles of land. Cumulative initial production of wells in the field totaled approximately 6500 bbl. a day at the end of the year, with the largest well producing

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Oakland City Brown sands	MisU	S	Por	630 1,080 1,130	640 1,100 1,140	*x*	A	St. Louis	1,413
2	Mansfield	PenL	S	25	1,007	1,031	30	ML	Chester	1,920
3	Tar Springs, Cypress, Elwren	MisU	S	Por	330	350	20	ML	Mis Lime	710
4	L. Chester	MisU	S	Por	630	640	*y*	A	Chester	895
5	Cunningham	MisU	S	Por	1,525	1,530	*y*	*y*	Ste. Genevieve	1,654
6	Brown, McClosky	MisU	S, OL	Por	1,430	1,450	25	A	Ordovician	4,006
7	Trenton	Ord	L	Por	886	907	*y*	A	Pre-Cambrian	3,055
8	Waltersburg, Tar Springs, Elwren, AuxVases, McClosky	MisU MisM	S1, 2, 3, 4; L 5	Por	2,150	2,900	*y*	AF	Salem	3,185
9	Mooretown	MisU	S	Por	1,110	1,125	*y*	A	Ste. Genevieve	1,321
10	New Albany	DevU	H	Fis	650	680	*y*	M	Trenton	1,770
11	Waltersburg, Tar Springs	MisU	S	Por	1,750 1,855	1,800 1,920	*y*	AF	Ste. Genevieve	2,643
12	Barker sand	MisU	S	Por	650	660	10	T	St. Louis	1,575
13	Chester	MisU	S	Por	532	540	15	A	Trenton	3,025
14	Mansfield, Cypress, Mooretown, Paoli	PenL MisU	S L	Por	1,225 1,475 1,535	1,240 1,560	*y*	M	Ste. Genevieve	1,569
15	Waltersburg, Tar Springs, McClosky	MisU	S OL	Por	2,150	2,900	31	A	St. Louis	3,028
16	Oakland City, Brown	MisU	S	Por	1,085 1,112	1,107 1,126	*y*	A	Paoli	1,444
17	Staunton	PenL	S	Por	580 790	610 802	*y*	ML	Mis Lime	1,593
18	Sample, Cypress, Mooretown, Paoli	MisU	S L	Por	1,250 1,270 1,340 1,725	1,270 1,290 1,360 1,740	T	A	Harrodsburg	2,050
19	Corniferous, Niagara	DevM SilM	L	Por	2,074	2,165	*y*	D	Silurian	2,232
20	Sample	MisU	S	Por	1,310	1,320	*y*	MC	Mis Lime	1,500
21	Palestine	MisU	S	Por	885	905	10	*y*	St. Louis	1,707
22	Unnamed 1, 2, 3, 4, Harrodsburg, Niagara	PenL MisM, SilM	S L	Por	298, 545 640, 730 800 1,400, 2,270	325, 560 667, 775 810, 1,500 2,285	*y* *y*	AM	Silurian	2,870
23	Corniferous, Niagara	DevM SilM	L	Por	2,100	2,115	*y*	D	Trenton	3,554
24	Trenton	Ord	L, D	Por	900	1,250	*y*	A	Pre-Cambrian	3,996
25	Brazil, Oakland City	PenL MisU	 S	 Por	315 1,317	331 1,335	*y*	A	Ste. Genevieve	1,998
26	Sample, Cypress, Mooretown	MisU	S	Por	468, 714 747, 805 1,168	492, 728 759, 827 1,195	*y*	N MF	Mis Lime	1,708
27	Cypress, Mooretown, Paoli	MisU	S	Por	945 1,233	950 1,250	*y*	A	Salem	2,205
28	Devonian	DevM	L	Por	800	850	40	AF	Trenton	2,102
29	Mansfield	PenL	S	Por	899	911	*y*	ML	Glen Dean	1,795
30	Veale (McClosky)	MisM	OL	Por	1,161	1,169	*y*	A	Devonian	2,618
31	W. Princeton	PenL	S	Por	890	920	*y*	A	St. Louis	3,905
32										

TABLE 2.—*Summary of Drilling Operations in Indiana*

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rge.		
1	Blackford	15	24 N	11 E	1,635	Silurian
2	Blackford	20	24 N	11 E	3,302	Silurian
3	Cass	11	28 N	1 W	1,373	Devonian
4	Daviess	2	2 N	5 W	3,025	Pennsylvanian
5	Daviess	29	4 N	5 W	870	Pennsylvanian
6	Dubois	18	3 S	5 W	1,050	Pennsylvanian
7	Dubois	12	2 S	5 W	866	Pennsylvanian
8	Gibson	18	2 S	10 W	2,111	Pennsylvanian
9	Gibson	8	2 S	11 W	2,353	Pennsylvanian
10	Gibson	22	2 S	11 W	2,240	Pennsylvanian
11	Gibson	36	1 S	10 W	1,999	Pennsylvanian
12	Gibson	26	3 S	14 W	2,926	Pennsylvanian
13	Gibson	13	2 S	11 W	2,200	Pennsylvanian
14	Gibson	9	4 S	11 W	2,544	Pennsylvanian
15	Gibson	13	3 S	13 W	2,850	Pennsylvanian
16	Gibson	26	3 S	14 W	2,952	Pennsylvanian
17	Gibson	27	2 S	12 W	2,581	Pennsylvanian
18	Gibson	13	3 S	9 W	963	Pennsylvanian
19	Gibson	25	1 S	12 W	2,405	Pennsylvanian
20	Gibson	19	3 S	13 W	2,955	Pennsylvanian
21	Gibson	27	3 S	14 W	2,518	Pennsylvanian
22	Gibson	3	2 S	11 W	3,905	Pennsylvanian
23	Gibson	15	2 S	9 W	1,638	Pennsylvanian
24	Gibson	25	3 S	13 W	2,808	Pennsylvanian
25	Gibson	8	3 S	13 W	2,883	Pennsylvanian
26	Gibson	18	3 S	13 W	3,001	Pennsylvanian
27	Harrison	8	1 S	4 E	1,935	M. Mississippian
28	Jackson	11	5 N	2 E	2,475	Borden (L Mis)
29	Jasper	28	31 N	5 W	1,112	Devonian
30	Johnson	21	11 N	4 E	1,889	Borden (L Mis)
31	Knox	Sur. 9	1 N	11 W	2,081	Pennsylvanian
32	Knox	Don. 54	3 N	9 W	3,241	Pennsylvanian
33	Knox	Lot 44	2 N	10 W	1,934	Pennsylvanian
34	Knox	11	2 N	11 W	2,018	Pennsylvanian
35	Knox	27	5 N	8 W	1,276	Pennsylvanian
36	Knox	Lot 141	1 N	12 W	2,338	Pennsylvanian
37	Knox	Don. 214	5 N	9 W	2,256	Pennsylvanian
38	Knox	Don. 224	2 N	8 W	3,000	Pennsylvanian
39	Knox	21	2 N	9 W	1,785	Pennsylvanian
40	Knox	23	1 N	10 W	3,510	Pennsylvanian
41	Knox	14	1 S	12 W	2,402	Pennsylvanian
42	Marion	34	17 N	3 E	965	Devonian
43	Martin	36	4 N	5 W	559	Pennsylvanian
44	Martin	4	2 N	4 W	450	Pennsylvanian
45	Monroe	29	8 N	1 E	2,502	L. Mississippian
46	Orange	29	3 N	2 W	3,226	Pennsylvanian
47	Pike	30	1 N	6 W	728	Pennsylvanian
48	Pike	18	2 S	7 W	1,566	Pennsylvanian
49	Posey	35	6 S	12 W	2,168	Pennsylvanian
50	Posey	17	7 S	14 W	3,021	Pennsylvanian
51	Posey	30	7 S	14 W	2,937	Pennsylvanian
52	Posey	35	3 S	14 W	3,144	Pennsylvanian
53	Posey	19	6 S	12 W	2,735	Pennsylvanian
54	Posey	31	3 S	13 W	3,047	Pennsylvanian
55	Posey	13	6 S	13 W	2,915	Pennsylvanian
56	Posey	9	4 S	12 W	2,800	Pennsylvanian
57	Posey	10	4 S	13 W	3,003	Pennsylvanian
58	Posey	1	5 S	13 W	2,980	Pennsylvanian
59	Posey	10	5 S	14 W	2,985	Pennsylvanian
60	Posey	34	6 S	12 W	2,811	Pennsylvanian
61	Posey	1	7 S	12 W	1,888	Pennsylvanian
62	Posey	13	7 S	13 W	2,720	Pennsylvanian
63	Spencer	11	5 S	6 W	1,358	Pennsylvanian
64	Spencer	9	6 S	4 W	1,070	Pennsylvanian
65	Spencer	24	6 S	5 W	1,015	Pennsylvanian
66	Spencer	11	6 S	7 W	1,583	Pennsylvanian

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	St. Peter	A. Murray Jones			Dry hole
2	Cambrian	A. S. Reed			Show oil in Trenton and at 2300 ft.
3	St. Peter	Fred W. Eastman			Show oil
4	Devonian	Midwest Development			Dry hole
5	McClosky	Neely-Young			Dry hole
6	McClosky	Fred Phillips			Dry hole
7	McClosky	C. C. Taliaferro			Show oil 740
8	McClosky	Cleary & Tharp			Dry hole
9	McClosky	W. F. Armstrong			Dry hole
10	McClosky	H. H. Lawson			Dry hole
11	McClosky	Davis, McElreath, Suggett			Dry hole
12	McClosky	Fitzpatrick & Hayes			Delimit Griffin
13	McClosky	Longhorn Oil Co.	25		Deeper production near W. Princeton
14	St. Louis	J. L. Taylor			Dry hole
15	McClosky	Continental Oil Co.			Show oil 1138–1143, 2366–2379
16	McClosky	Gwin Drilling Co.	Est. 400		Extension, Griffin
17	McClosky	J. S. Young			Dry hole
18	Pennsylvanian	A. J. Walker	30		Discovery, Mackey
19	McClosky	Michel Bros. Co.			Show oil, hole junked
20	St. Louis	J. B. Bond			E. limit, Griffin
21	Elwren?	Continental Oil Co.	35/1 hr.		Extension, Griffin
22	Silurian	L. H. Choate et al.			Devonian test in old W. Princeton field
23	McClosky	Midwest Development	Est. 50		Ext., W. Francisco
24	McClosky	W. R. Nicholson			Dry hole
25	McClosky	W. F. Lacy	Oil—no gauge		Extension, Griffin
26	St. Louis	Ray Ryan			Delimit Griffin
27	Trenton	A. E. Wenning			Dry hole
28	St. Peter	Siosi Co.—W. B. Pardoe			Dry hole
29	Trenton	United Development Corp.			Show oil in Trenton
30	St. Peter	Wissing, Smith, McCoun			Dry hole
31	McClosky	Michel Bros. Co.			Dry hole
32	Devonian	Midwest Development			Dry hole
33	McClosky	A. C. Thomas			Show oil
34	McClosky	Midwest Development	Oil—no gauge		
35	McClosky	Young & Bode			Dry hole
36	McClosky	R. S. Young			Dry hole
37	L. Mississippian	M. I. T. Syndicate			Dry hole
38	Devonian	Uland & Umfleet			Dry hole
39	McClosky	Cherry & Kidd			Dry hole
40	Devonian	Parshall-Graham	40		
41	McClosky	Horton & Wiggins			Dry hole
42	Trenton	C. E. Jefferson			Show oil and Gas 940–944
43	McClosky	Newton Pipe Line Co.			Show oil 292–298, 492–502
44	McClosky	Norris & Gilmore			Show oil 402
45	St. Peter	W. B. Pardoe, Trustee			Dry hole
46	St. Peter	R. S. Hayes			Dry hole
47	Hardinsburg	Walker & Rogers		0.250	
48	McClosky	W. O. Allen, Jr			Dry hole
49	Chester	Sun Oil Co.			Delimit Heusler
50	St. Louis	A. Wilhelmi			Dry hole
51	Ste. Genevieve	Ryan & Brown			Dry hole
52	St. Louis	Minton & Lewis	28		Extension Griffin
53	Ste. Genevieve	Haynes-Thomas	Oil—no gauge		Plug back 409 (Penn)
54	St. Louis	Superior Oil Co. (Calif.)	41		Extension Griffin
55	Ste. Genevieve	Gulf Refining Co.			Dry hole
56	McClosky	Kenillind Oil Co.			Dry hole
57	St. Louis	Tide Water Assoc. Oil Co.			Dry hole
58	Ste. Genevieve	Evans Oil & Gas Co.			Dry hole
59	McClosky	Superior Oil Co. (Calif.)	250		Discovery: New Harmony
60	Ste. Genevieve	Sun Oil Co.			Dry hole
61	Tar Springs	Illind Oil Co.	124 flow 350 pump		Extension Heusler
62	Ste. Genevieve	Clint Crosby	75		Later abandoned
63	McClosky	J. R. Knapp			Dry hole
64	McClosky	Kelly, Thomas, Flanders			Dry hole
65	McClosky	D. P. Hynes	36		
66	McClosky	LeMoine & Taylor			Dry hole

initially 1200 bbl. Production is from the Waltersburg sand from a depth of a little more than 2100 ft. Small production has been also obtained in the New Harmony field from the Tar Springs and McClosky horizons. As much as 60 ft. of good saturation has been cored in the Waltersburg sand.

The outstanding discovery of natural gas during the year was the opening of the new Rockport field in Spencer County, T. 7 S., R. 6 W. The discovery well produced initially 4.43 million cu. ft. from the Palestine (Upper Chester) sandstone at a depth of 888 ft. At the close of the year, 13 producing wells had been completed, varying in initial production from 2.5 to 15.00 million cu. ft. a day. The total cumulative initial production in this field was 100.360 million cu. ft. a day on Jan. 1, 1940. Oil in paying quantities had not been encountered in the field at the end of the year, although at least one well, somewhat off the structure, had a good show.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rge.		
67	Spencer	8	7 S	6 W	1,590	Pennsylvanian
68	Spencer	17	6 S	6 W	2,500	Pennsylvanian
69	Spencer	28	6 S	5 W	1,219	Pennsylvanian
70	Spencer	29	7 S	6 W	902	Pennsylvanian
71	Spencer	32	6 S	7 W	1,016	Pennsylvanian
72	Spencer	32	7 S	7 W	1,776	Pennsylvanian
73	Spencer	2	8 S	7 W	1,412	Pennsylvanian
74	Spencer	7	7 S	7 W	1,783	Pennsylvanian
75	Spencer	29	6 S	6 W	1,544	Pennsylvanian
76	Spencer	19	7 S	6 W	892	Pennsylvanian
77	Spencer	34	7 S	6 W	1,552	Pennsylvanian
78	St. Joseph	8	37 N	1 E	1,637	Devonian
79	Sullivan	18	8 N	10 W	2,825	Pennsylvanian
80	Sullivan	20	8 N	9 W	2,515	Pennsylvanian
81	Tipton	21	21 N	3 E	1,521	Devonian
82	Vanderburgh	6	7 S	11 W	2,628	Pennsylvanian
83	Vanderburgh	8	6 S	11 W	1,325	Pennsylvanian
84	Vanderburgh	14	6 S	11 W	2,648	Pennsylvanian
85	Vanderburgh	17	5 S	11 W	2,735	Pennsylvanian
86	Vanderburgh	8	6 S	11 W	1,820	Pennsylvanian
87	Vanderburgh	7	7 S	11 W	1,908	Pennsylvanian
88	Vanderburgh	5	7 S	11 W	1,797	Pennsylvanian
89	Vigo	21	11 N	8 W	1,802	Pennsylvanian
90	Vigo	20	10 N	10 W	2,296	Pennsylvanian
91	Vigo	33	11 N	9 W	2,190	Pennsylvanian
92	Vigo	13	13 N	9 W	1,617	Pennsylvanian
93	Warrick	9	6 S	7 W	1,633	Pennsylvanian
94	Warrick	12	6 S	9 W	2,107	Pennsylvanian
95	Warrick	32	4 S	6 W	2,813	Pennsylvanian
96	Warrick	34	5 S	8 W	1,961	Pennsylvanian
97	Warrick	14	5 S	9 W	1,960	Pennsylvanian
98	Warrick	12	6 S	8 W	1,859	Pennsylvanian
99	Wayne	19	13 N	1 W	908	Ordovician
100	Wayne	24	13 N	2 W	473	Ordovician

Good McClosky limestone production was found by the Midwest Development Corporation, a little north of the old Francisco area in eastern Gibson County (Louis Wirth No. 1). Three wells had been drilled in this area at the end of the year. Deeper production or extensions to old fields added new life to several areas.

One-well fields awaiting further development in 1940 included: Millersburg, sec. 14, T. 5 S., R. 9 W., total depth 1960 ft., initial production 70 bbl. a day; Unnamed, sec. 32, T. 6 S., R. 7 W., total depth 1016 ft., initial production 16 bbl. a day, gravity 34°; Mackey, sec. 13, T. 3 S., R. 9 W., total depth 963, initial production 60, settled 30 bbl a day;

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
67	McClosky	W. W. Damron			Dry hole
68	L. Mississippian	W. S. Tatum			Dry hole
69	McClosky	A. J. Early et al.			Dry hole
70	Palestine	O. F. Kelly		12.118	Extension Rockport
71	Chester	Trio Oil Co.	16		
72	McClosky	C. D. Neff			Dry hole
73	L. Chester	Frank Damron	20		Discovery, Enterprise field
74	McClosky	Sycamore Oil Co.			Dry hole
75	McClosky	A. A. Douglas			Dry hole
76	Palestine	W. W. Damron		4.43	Discovery, Rockport gas. Casing pressure, 380 lb. per sq. in.
77	McClosky	Frank Damron			Dry hole
78	Trenton	K. G. Nilsen			Dry hole
79	Devonian	Siosi Co.-W. B. Pardoe			Dry hole
80	Devonian	Hawaiian-Amer. Exploration Co.			Dry hole
81	St. Peter	Fred W. Eastman			100 M gas, 994-999
82	McClosky	Superior Oil Co. (Calif.)			Delimit Heusler
83	U. Chester	John Baumgart			Dry hole
84	McClosky	Travis-McIntyre			Dry hole
85	St. Louis	Arab Petroleum Co.			Dry hole
86	Chester	R. E. Moore			Dry hole
87	Chester	M. L. Glaser			Dry hole
88	Chester	Earl Ford et al.			Dry hole
89	Devonian	Carl Robinson			Dry hole
90	Silurian	Vandenbark & Whitaker			Delimit Prairie Creek
91	Devonian	Ben H. Nation			Dry hole
92	Devonian	W. Spencer			Dry hole
93	McClosky	Hoosier Drilling Co.			Dry hole
94	McClosky	Gulf Refining Co.			Dry hole
95	Devonian	L. T. Phillips			Dry hole
96	McClosky	Walsh-Dye			Dry hole
97	McClosky	McWilliams-Schwartz	70		
98	McClosky	Imperial Oil & Gas Co.			Dry hole
99	Trenton	John M. Seip			Show oil and gas (855)
100	M. Ordovician	John M. Seip		0.20	New producing horizon
	Total........		2271+	16.998	

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939..	38	39
Number of oil wells completed during 1939..................................	156	19
Number of gas wells completed during 1939.................................	39	5
Number of dry holes completed during 1939.................................	60	98

Unnamed, sec. 11, T. 2 N., R. 11 W., total depth 2018, small oil well; Unnamed, sec. 23, T. 1 N., R. 10 W., total depth 3510, plugged back to approximately 2000 ft., initial production 40 bbl. a day. It is not known whether these prospects will result in commercial oil fields or whether they are merely "pockets" of oil as sometimes encountered. It is probable, however, that some future production may be expected in at least some of these areas.

Pipe-line proration, limiting oil wells to two-thirds of their potential, continued on some of the older fields of the state. Many of these older fields failed to make even their 1938 allowable. Total production of oil in Indiana during 1939 was 1,729,564 bbl. This is 60 per cent more oil than was produced in the state during 1938. Production of natural gas continued to decline from 1244 million cu. ft. in 1938 to 871.586 million cu. ft. in 1939. The new Rockport field had no pipe-line connections until the latter part of December and no gas was sold from the field until after the end of the year. Many of the older gas fields in the state are nearing their economic limit and probably will be abandoned in the next few years.

Leasing activity has declined considerably in southwestern Indiana, since most of the desirable acreage is now under lease. A large number of operators are interested in other parts of the state and are taking large blocks of acreage accordingly. It is probable that activity in 1940 will be as great or greater than in 1939, since many thousands of acres under lease are awaiting favorable weather for testing operations to commence.

Kansas Oil and Gas during 1939

By W. A. Ver Wiebe*

(New York Meeting, February 1940)

The year 1939 in Kansas, with a production of 57,944,300 bbl. from 19,669 wells, shows a slight recession from the peak of oil production reached the previous year, when slightly over 59,000,000 bbl. of oil was marketed. The previous peak had been reached in 1917 with 45,451,000 bbl. marketed. Another still earlier peak had been reached in 1904, when slightly less than 5,000,000 bbl. was produced and sold. The production of gas probably reached a new peak during 1939 with a total of over 69 billion cubic feet. Between the peak of the year 1908, when over 80 billion cu. ft. was produced, and that of 1939 the production dropped to 16 billion cu. ft., in the year 1921.

During the year 1458 wells were drilled. This figure is somewhat lower than that given in several trade journals, because it does not include wells that were deepened or recompleted in a different geological horizon. Nearly 75 per cent (1029) of the total number of wells were completed as commercial oil wells (824 in western and 205 in eastern Kansas). The commercial gas wells completed number 71, of which 24 are in eastern Kansas and 47 in western Kansas. The remaining completions include 154 dry holes in eastern and 204 dry holes in western Kansas. Based on daily potential capacity the new discoveries of the year accounted for a cumulative initial production of 264,000 bbl. in eastern and 1,158,827 bbl. in western Kansas.

It is interesting in this connection to note that the number of wells completed in the state rose gradually to a first peak in 1904, when 2782 were drilled. The number dropped off rapidly to 368 three years later, but rose to the second and highest peak in 1918, when 4671 wells were completed. In the period between 1904 and 1912 more gas wells than oil wells were completed. Between the high peak of 1918 and the somewhat lower peak of 1937, the low point was reached during 1931 with the completion of only 470 wells.

In the matter of new pools discovered, Kansas again ranks high. The exact number depends somewhat upon the interpretation of a "new" area—whether it should be called a new pool or a long extension of an older pool. In some places this determination cannot be made until more wells are drilled within the area. Therefore, the figures given

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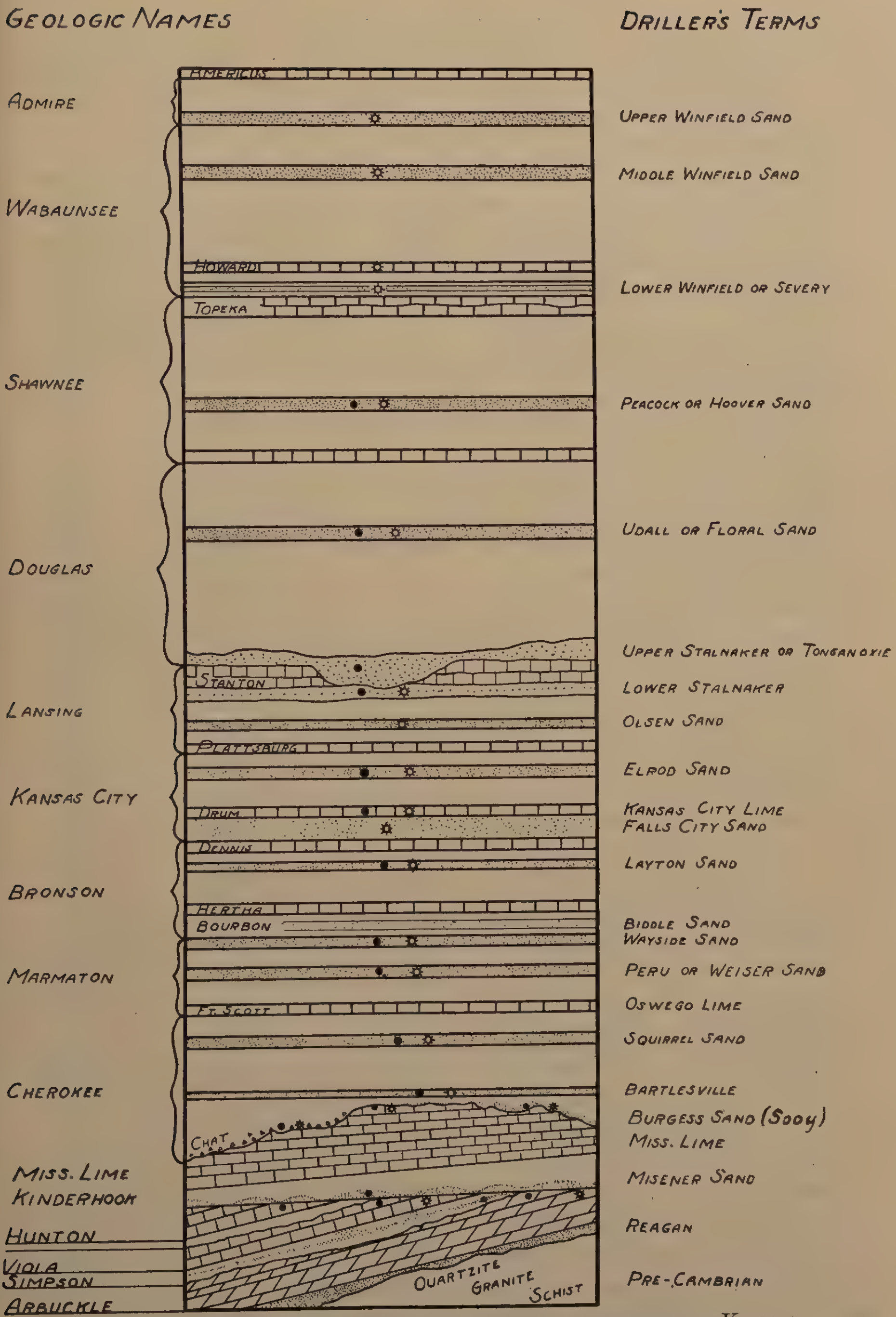

Fig. 1.—Producing horizons of western and southern Kansas. Drawn by Edgar Rehn from data supplied by the author.

in this report may differ from those presented in the trade journals. Table 2 lists 20 new oil pools and 2 new gas pools. Trade journals are also inclined to list as new pools the areas in which oil is discovered in new producing horizons in old pools. During 1939 discoveries of this type were made in 17 areas. Of this total 15 new oil discoveries were made in new horizons present in old pools, while the other two were new horizons discovered in pools previously found during the year 1939.

New Geological Information.—In most cases the new horizons were the same as those found productive elsewhere in the state. It is common, for example, to find the Arbuckle productive in a pool having production from the Lansing-Kansas City (formerly called Oswald), or vice versa. Less often the new horizon is the Simpson (sometimes called the Wilcox) or a formation in the Pennsylvanian system.

Producing horizons of western and southern Kansas are shown in Fig. 1.

Most Active Pools.—The most active pools in Kansas during the year were the Hittle pool, Cowley County; the Bemis pool, Ellis County; the Burnett pool, Ellis County; the Bornholdt pool, McPherson County; and the Trapp pool, Russell County. Important extensions were made to a large number of pools during the year. In Barton County the Bloomer pool was extended in several directions and now has 140 wells as compared to 90 at the end of the preceding year. In addition, a new producing horizon, the Pennsylvanian basal conglomerate was found productive in one well. In the northeastern part of the county there was much drilling in and near the Prusa pool, resulting in the addition of 17 new wells and 2 new producing horizons—the Lansing-Kansas City and the Granite Wash. Also, two new pools, called Prusa North and Prusa West, were discovered near by as a result of the efforts to extend the Prusa pool. In Cowley County a large number of wells were drilled during the year, resulting in the discovery of two new pools, the Darien and Rahn, and very important extensions to old pools. The important extensions were made in the Frog Hollow pool, which now has 20 wells as compared to 8 at the end of the preceding year; and in the Hittle pool, which now has 61 wells as compared to 19 at the end of the previous year. In Ellis County the Bemis pool was increased by 45 wells and was also enlarged by being joined to the old Shutts pool. The name of the new pool is Bemis-Shutts. The Burnett pool has 65 wells, compared to 10 at the end of the previous year, and the Walter pool has 33 wells as compared to 24. In Ellsworth County, the most important changes are due to the fact that many wells in the Lorraine pool were plugged back to the level of the Lansing-Kansas City limestone. In the Graham County Morel pool four additional wells were drilled, bringing the total up to five. In Kingman County the Cunningham pool was extended and now has 41 wells, as compared to 36 at the close of the preceding year.

TABLE 1.—*List of Producing Oil Fields*

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Barber County			91,958	826,765	13				
Lake City 7-31-13W	July 1937	160	12,035	29,485	1 1	Viola Arbuckle	4,435 4,607	5 4	Lime Dolomite
Medicine Lodge 13-33-13W	March 1937	80	13,420	28,829	2	Misener	4,845	2	Lime
Whelan 32-31-11W	Aug. 1934	640	66,503	243,625	9	Chat	4,355	29	IR
Barton County			7,163,458	30,854,406	959				
Ainsworth 22-16-13W	Dec. 1936	5,000	479,948	1,209,362	1 58	Oread Arbuckle	2,925 3,390	4 5	Lime Dolomite
Albert 30-18-15W	Jan. 1935	1,200	221,176	455,000	14	Reagan	3,601	15	Sandstone
Beaver 16-16-12W	Dec. 1934	1,000	139,311	667,626	1 19	Oread Arbuckle Reagan	2,900 3,348 3,335	6 3 6	Lime Dolomite Sandstone
Beaver North 4-16-12W	Oct. 1937	160	124,643	157,950	3	Arbuckle	3,316	10	Dolomite
Bloomer 36-17-11W	Feb. 1936	4,000	792,655	3,449,126	33 1 109	Lans. K. C. Sooy Arbuckle	3,044 3,310 3,257	10 24	Lime Conglomerate Dolomite
Boyd 3-18-14W	Dec. 1938					Arbuckle	3,365	2	Dolomite
Clawson 17-20-11W	Dec. 1938	600	150,354	150,354	6	Arbuckle	3,285	14	Dolomite
Davidson 4-16-11W	March 1928	80	8,784	37,214	1 1	Sooy Arbuckle	3,317 3,314	26 21	Dolomite Conglomerate
Eberhardt 14-19-11W	June 1935	160	22,379	131,880	4	Arbuckle	3,311	49	Dolomite
Ellinwood joined to Silica Sept., 1939									
Ellinwood North 33-19-11W	July 1937	80	10,215	32,369	1	Arbuckle	3,328	22	Dolomite
Ellinwood West 7-20-11W	Apr. 1938	160	41,020	59,489	4	Arbuckle	3,346	6	Dolomite
Feist 29-18-11W	Mar. 1936	40	5,114	41,435	1	Arbuckle	3,430	3	Dolomite
Feltes 14-16-12W	Nov. 1939	40	none		1	Sooy	3,342	2	Conglomerate
Hagan 20-20-11W	Dec. 1938	40	7,020	8,070	1	Arbuckle	3,323	7	Dolomite
Harzman 33-16-11W	Oct. 1939	40	355	355	1	Lans. K. C.	3,124	8	Lime
Heiser 16-19-14W	Aug. 1935	40	3,200	15,530	1	Lans. K. C.	3,228	25	Lime
Hiss 31-20-13W	Feb. 1936	160	33,830	212,798	4	Lans. K. C.	3,270	20	Lime
Hoisington 21-17-13W	Jan. 1938	160	11,650	26,635	1 2	Lans. K. C. Arbuckle	3,222 3,440	5 12	Lime Dolomite
Kraft 10-17-11W	March 1937	2,200	260,160	614,518	38	Arbuckle	3,281	8	Dolomite
Krier 30-16-11W	Oct. 1939	80	3,725	3,725	2	Sooy	3,327		Conglomerate
Kruckenberger 14-19-15W	Jan. 1939 Apr. 1939	160	5,839	5,839	1 1	Lans. K. C. Arbuckle	3,342 3,580	53 5	Lime Dolomite
Lanterman 15-19-11W	Jan. 1935	200	43,350	165,647	4 2	Lans. K. C. Arbuckle	3,109 3,235	6 3	Lime Dolomite
Odin 10-17-12W	May 1938	80	4,840	13,486	1	Arbuckle	3,340	2	Dolomite
Pospishel 20-17-15	June 1939	80	3,645	3,645	2	Arbuckle	3,548	9	Dolomite
Prusa 20-16-11W	Dec. 1938	800	116,363	116,363	2 15 2	Lans. K. C. Arbuckle Reagan	3,160 3,335 3,310	7 17 1	Lime Dolomite Granite Wash
Prusa North 18-16-11W	Sept. 1939 May 1939	80			2	Lans. K. C. Arbuckle	3,160	7	Lime Dolomite
Prusa West 18-16-11W	June 1939	40	8,958	8,958	1	Lans. K. C.	3,207	10	Lime
Rick 1-19-11W	Aug. 1936	160	33,440	169,265	5	Arbuckle	3,355	2	Dolomite
Silica 12-20-11W	Oct. 1931	20,000	4,670,170	23,136,453	7 617	Lans. K. C. Arbuckle	2,955 3,328	95 19	Lime Dolomite

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Silica South joined to Silica Sept., 1939									
Trapp (see Russell County)									
Wolf joined to Ellinwood West Jan. 1940									
Butler County			4,842,811		2,690				
Augusta North 28-27-4E	Jan. 1914	1,280	141,620	13,196,352	68	Kans. City	1,900	35	Lime
						Layton	2,000		Sandstone
						Wilcox	2,380	10	Sandstone
						Arbuckle	2,410	5	Dolomite
Augusta South 21-28-4E	Jan. 1916	9,000	303,315	33,239,748	149	Kans. City			Lime
						Ft. Scott			Lime
						Wilcox	2,445	10	Sandstone
						Arbuckle	2,600	5	Dolomite
Bausinger 24-27-3E	July 1929	200	8,760		5	Wilcox	3,050	29	Sandstone
Benton 10-26-3E	Jan. 1925	80	4,380		2	Chat	2,765	5	IR
Blankenship 2-26-8E	Jan. 1921	1,200	78,475		90	Bartlesville	2,650	50	Sandstone
Brandt 15-28-7E	June 1936	800	19,860	199,197	20	Chat	2,692	8	IR
DeMoss 5-28-7E	Oct. 1924	400			10	Bartlesville	2,700		Sandstone
						Burgess	2,732	10	
Douglass 2-29-4E	Jan. 1916	2,400	25,550		22	Lans. K. C.	1,790	40	Lime
						Varner	2,835	50	
Elbing 8-23-4E	Aug. 1918	1,800	401,500		88	Lans. K. C.	2,330	70	Lime
						Viola	2,430	40	
El Dorado 29-25-5E	Jan. 1917	25,000	2,700,950	174,618,269	1,649	Admire	600	10	Sandstone
						Lans. K. C.	1,700	20	Lime
						Viola	2,500	5	Lime
						Simpson	2,510	15	Sandstone
						Arbuckle	2,550	5	Dolomite
Ferrell 28-28-8E	Mar. 1939	80	15,911	15,911	2	Mis. lime	2,647	42	Lime
Fox Bush 25-28-5E	Jan. 1917	5,000	135,050		164	Bartlesville	2,730	40	Sandstone
Garden 32-26-6E	Mar. 1928	1,600	59,860		30	Bartlesville	2,760	10	Sandstone
Gelwich 6-27-4E	Apr. 1930	80	14,600		2	Viola	2,924	2	Lime
Haverhill (15-34)-27-5E	Apr. 1927	700	78,840	3,033,243	61	Bartlesville	2,700	50	Sandstone
Keighley (14-33)-27-7E	Jan. 1925	1,800	54,750		51	Bartlesville	2,650	50	Sandstone
King 17-24-4E	Jan. 1937					Kans. City	2,145	120	Lime
Kramer 4-28-6E	Jan. 1926	500	44,895		19	Viola	3,050	3	Lime
						Wilcox	3,020	15	Sandstone
						Arbuckle	3,040	5	Dolomite
Leon 19-27-6E	Oct. 1926	500	29,565		22	Chat	2,660	50	IR
						Viola	3,050		Lime
McCullough 1-28-6E	Feb. 1926	400	69,560	304,795	8	Wilcox	3,169	6	Sandstone
McCaig 13-28-6E	Mar. 1937	80	5,255	18,400	2	Bartlesville	2,720	20	Sandstone
Madden 27-23-4E	May 1937					Lans. K. C.	2,065	147	Lime
Moore 12-25-3E		120	7,300		3	Mis. lime	2,667	9	Lime
Pettit 21-28-6E	July 1936	Abandoned				Wilcox	3,160	3	Sandstone
						Mis. Lime	2,826	4	Lime
Potwin 36-24-3E	Jan. 1921	3,200	266,450		83	Kans. City	2,250	5	Lime
						Mis. Lime	2,660	95	Lime
Shaffer 4-27-6E	June 1926	900	118,990		27	Mis. Lime	2,760	10	Lime
						Viola	3,125	25	Lime
Seward 14-27-7E		600	17,520	932,200	14	Bartlesville	2,650	50	Sandstone
Smock-Sluss 19-26-6E	Mar. 1918	1,500	63,875		42	Bartlesville	2,685	30	Sandstone
						Viola	3,000		

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Snowden-McSweeney 2-29-6E	1930	160	4,015		1	Mis. lime	2,833		Lime
Steinhoff 21-29-6E	Jan. 1926	160	4,745		3	Chat	2,803	5	IR
Stern 27-27-6E	Jan. 1928	600	85,000		16	Chat Viola	2,752 3,150	8	IR
Weaver 1-28-5E	Jan. 1929	400	3,285		8	Bartlesville	2,690		Sandstone
Young 27-26-7E	1919	900	79,205		29	Kans. City Chat	2,190 2,650	5 50	Lime IR
Clark County									
Morrison 17-32-21W	Oct. 1936	160	28,560	95,650	2	Viola	6,467	4	Lime
Coffey County									
Van Noy (1-14)-23-14E (6-18)-23-15E		700	19,345		36	Peru Chat	1,138 1,622	12 6	Sandstone IR
Cowley County			3,376,997		633				
Baird 16-34-3E		160	4,380		4	Bartlesville	3,260		Sandstone
Biddle 12-32-4E		600	39,055		22	Stalnaker Kans. City Arbuckle	2,300 2,600		Sandstone Lime Dolomite
Biddle West 11-32-4E	Sept. 1932								
Burden 22-31-6E	Jan. 1926	1,200	64,240		33	Bartlesville	2,865	35	Sandstone
Brown 13-31-7E	Sept. 1922	40	1,825		1				
Carson 19-32-3E	Oct. 1924	400	56,735	2,989,558	17	Layton Arbuckle	2,600 3,450		Sandstone Dolomite
Clarke 6-31-4E	Jan. 1914	180	14,235		4	Bartlesville	2,840		Sandstone
Countryman 4-33-7E		600	9,125		5	Layton	1,950		Sandstone
Darien 33-30-4E	June 1939	200	18,536	18,536	6	Arbuckle	3,286	1	Dolomite
David 35-30-4E	July 1935	800	136,650	366,876	17	Bartlesville	2,935	40	Sandstone
David South 11-31-4E	Jan. 1934	200	16,060		5 1	Bartlesville Arbuckle	3,010 3,463	19 3	Sandstone Dolomite
Dexter 24-33-6E	Jan. 1903	1,200	4,015		1	Mis. lime	2,750		Lime
Dunbar 29-30-5E	Sept. 1938	40	2,327	5,209	1	Kans. City	2,229	36	Lime
Eastman 31-30-6E	Jan. 1924	1,200	53,290	2,289,124	33	Bartlesville	2,770	100	Sandstone
Elrod 4-32-5E	June 1918					Elrod sand	2,390	10	Sandstone
Falls City 17-35-7E	Jan. 1916	600	14,940	1,152,276	13	Stalnaker	2,000		Sandstone
Ferguson West 21-30-8E		200	15,000		5				
Frog Hollow 20-32-5E	Jan. 1937	600	206,760	285,056	19	Bartlesville	3,089	8	Sandstone
Geuda Springs 8-34-3E	May 1936	600	94,114	219,544	10 1	Bartlesville Chat	 3,320		Sandstone IR
Graham 9-33-3E	June 1924	800	30,295	2,443,337	15	Layton Arbuckle	2,550 3,500		 Dolomite
Grand Summit 10-31-8E		600	28,470		14				
Hittle 21-31-4E	Jan. 1926	2,400	1,132,120		69	Stalnaker Arbuckle	2,400 3,280	 8	 Dolomite
Mahannah 6-30-8E	1918	80	13,505		2	Burgess	2,730		Conglomerate
Murphy 8-35-3E	Jan. 1933	600	39,420		12	Chat	3,300		IR
Olsen 1-35-7E	Apr. 1921	300	6,205		7	Ft. Scott	2,400		Lime
Rahn 13-34-5E	Oct. 1939	40	230	230	1	Bartlesville	2,915	30	Sandstone
Rainbow Bend 20-33-3E	Dec. 1923	2,000	397,750	12,653,046	115	Burgess	3,200	50	Sandstone

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Reidy 31-31-8E		160	2,190		3				
Rock 15-30-4E	Jan. 1923	500	68,255	1,421,993	25	Bartlesville	2,760	45	Sandstone
Rock West 16-30-4E	Oct. 1937	160	64,480	145,879	4	Bartlesville	2,784	18	Sandstone
Rock North 3-30-4E	Sept. 1937	200	20,910	30,713	5	Bartlesville	2,807	21	Sandstone
Smith 10-31-3E	Jan. 1917	600	14,235		12	Bartlesville	3,050		Sandstone
State 15-32-4E	Jan. 1926	1,500	72,270		32	Layton Arbuckle	2,300 3,500		Sandstone Dolomite
Trees 19-30-4E	Jan. 1934	300	70,080		10	Bartlesville	2,975	25	Sandstone
Turner 30-32-6E	June 1937	240	42,860	117,398	6	Layton	2,232	15	Sandstone
Udall 28-30-3E		40	2,190	45,466	1				
Wethered 28-31-3E	July 1935	1,000	476,095	1,698,720	2 2 27	Lans. K. C. Mis. lime Arbuckle	2,455 3,065 3,400	9 85	Lime Lime Dolomite
Wilson 9-33-6E	Nov. 1938	200	26,620	28,878	5	Arbuckle	3,519	4	Dolomite
Winfield 36-32-4E	Nov. 1914	5,000	117,530		63	Admire Peacock Layton Bartlesville Arbuckle	600 1,400 2,300		Sandstone Sandstone Sandstone Sandstone Dolomite
Edwards County McCarty temporarily abandoned. See gas pools.									
Elk County		5,000	244,750		260				
Moline 3-31-10E	Dec. 1927					Encill Mis. lime	1,150 1,980		Sandstone Lime
Sellars 11-31-9E						Mis. lime	2,300	22	Lime
Webb 28-31-10E	Oct. 1924					Encill. Red Ft. Scott Arbuckle	1,100 1,350 1,650 2,286		Sandstone Sandstone Lime Dolomite
Ellis County			3,481,279	10,929,507	478				
Bemis-Shutts 16-11-17W	Oct. 1935 Apr. 1936	5,200	2,309,615	7,841,663	 296	Topeka Arbuckle	3,032 3,380	8 2	Lime Dolomite
Bemis South 2-12-17W	Dec. 1938	40	8,775	8,775	1	Arbuckle	3,592	11	Dolomite
Blue Hill 14-12-16W	Aug. 1937	640	43,160	81,569	1 4 1 1	Topeka Lans. K. C. Arbuckle Wilcox	3,030 3,072 3,360 3,391	 33 25 1	Lime Lime Dolomite
Burnett 1-11-18W	Sept. 1937	2,000	297,510	325,621	1 63	Lans. K. C. Arbuckle	3,093 3,570	12 4	Lime Dolomite
Burnett South joined to Burnett May 1939									
Catherine 3-13-17W	June 1936	160	19,470	93,877	3	Lans. K. C.	3,262	88	Lime
Cress 13-11-17W	Mar. 1937	600	224,180	609,386	25	Arbuckle	3,293	9	Dolomite
Emmeram 4-13-16W	June 1937	40	7,670	28,591	1	Lans. K. C.	3,260	7	Lime
Hadley 20-11-17W	Aug. 1927	40			1	Lans. K. C.	3,428	12	Lime
Haller 10-11-18W	July 1936	40	1,560	11,887	1	Topeka	3,036	9	Lime
Koblitz 23-12-18W	Feb. 1937	100	615	2,608	3	Arbuckle	3,694	4	Dolomite
Kraus 22-14-9W	July 1936	100	8,570	45,811	2	Sooy	3,735	5	Conglomerate
Madden 26-15-18W	June 1936					Lans. K. C. Arbuckle	3,331 3,600	10	Lime Dolomite
Marshall 36-11-18W	Nov. 1936	1,000	106,350	359,579	14	Arbuckle	3,638	12	Dolomite

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Peavey joined to Burnett June 1939									
Penny Wahn........ 13-15-20W	Sept. 1936	40	6,570	19,083	1	Sooy	3,653	3	Conglomerate
Richards............ 5-11-18W	Jan. 1938	120	43,754	52,375	2	Lans. K. C.	3,332	41	Lime
Ruder............... 17-15-18W	Aug. 1935	700	83,880	566,473	14	Lans. K. C. Arbuckle	3,422 3,572	18 10	Lime Dolomite
Shutts joined to Bemis Sept. 1939									
Solomon............ 28-11-19W	June 1936	160	4,280	30,401	3	Arbuckle	3,629	3	Dolomite
Toulon.............. 3-14-17W	Dec. 1935	200	35,350	115,376	5	Lans. K. C. Arbuckle	3,298 3,512	5 48	Lime Dolomite
Ubert............... 12-13-18W	Nov. 1936	160	52,060	98,103	4	Arbuckle	3,707		Dolomite
Victoria abandoned..									
Walter.............. 2-12-18W	May 1936	1,200	227,910	638,329	1 31	Topeka Arbuckle	3,160 3,619	5	Lime Dolomite
Ellsworth County.........			1,174,735	13,074,063	167				
Breford............. 7-17-10W	Sept. 1932	700	119,500	918,312	11 6	Lans. K. C. Arbuckle	3,140 3,368	12 27	Lime Dolomite
Heiken............. 25-17-10W	Oct. 1930	320	18,250	324,446	5	Arbuckle	3,269	8	Dolomite
Lorraine............ 13-17-9W	Nov. 1934	5,500	602,635	7,290,204	22 66	Lans. K. C. Arbuckle	3,060 3,200	140 5	Lime Dolomite
Schroeder joined to Wilkins Apr. 1939									
Stoltenberg.......... 21-16-10W	June 1931	800	130,030	2,249,169	22	Arbuckle	3,333	14	Dolomite
Stratman........... 1-17-10W	Mar. 1931	600	79,220	1,924,125	17	Arbuckle	3,255	16	Dolomite
Wilkins (now includes Schroeder)........ 13-17-10W	Apr. 1934	800	225,100	367,807	19	Arbuckle	3,260	20	Dolomite
Finney County...........									
Nunn............... 27-21-34W	June 1938	800	35,220	53,105	2	Mis. lime	4,654	10	Lime
Graham County..........									
Morel.............. 15-9-21W	Apr. 1938	1,200	18,352	18,352	5	Arbuckle	3,718	2	Dolomite
Greenwood County........			3,012,670		2,610				
Atyeo-Pixlee......... 6-22-10E	Jan. 1923	1,000	127,750		96	Bartlesville	2,327	50	Sandstone
Blackwell........... 16-24-13E	Jan. 1923	1,000			5	Mis. lime	2,327		Lime
Brinegar............ 33-26-13E		500			31				
Browning........... 8-22-10E	Jan. 1924	3,800	148,555		93	Bartlesville	2,314	76	Sandstone
Burkett............. 13-23-10E	Jan. 1924	2,700	69,350		102	Bartlesville	2,000	100	Sandstone
Christy............. 36-24-12E		2,000	4,380		11	Bartlesville	1,500	75	Sandstone
DeMalorie-Souder... 19-21-10E	Jan. 1924	4,500	227,760		126	Bartlesville	2,150		Sandstone
Dunaway........... 4-22-13E		1,000	70,455		60	Mis. lime	1,800		Lime
Eureka............. 35-35-10E	Jan. 1920	1,200	23,725		15	Mis. lime	2,000		Lime
Fankhouser......... 32-21-12E	Jan. 1926	2,500	47,085		65	Bartlesville	1,750		Sandstone
Gaffney............. 6-24-11E	Aug. 1926	500	10,170	223,744	3				
Hamilton........... 26-23-11E	Jan. 1929	3,000	93,075		94	Bartlesville	1,765	72	Sandstone
Henley abandoned?..									
Hinchman.......... 17-24-13E		200	14,235		13	Mis. lime	1,600	50	Lime
Lamont............. 5-22-12E	Jan. 1927	2,600	124,465		108	Bartlesville	1,650		Sandstone
Madison............ 1-22-11E	Jan. 1921	3,000	185,055		102	Bartlesville	1,800		Sandstone

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Polhamus 27-24-9E	Jan. 1922	1,400	28,105		45	Bartlesville	2,170		Sandstone
Quincy 18-25-14E	Jan. 1926	3,600	205,860		115	Bartlesville	1,420		Sandstone
Reece 21-26-9E		1,200	47,815		21	Mis. lime	2,100		Lime
Sallyards 17-25-9E	Jan. 1921	8,000	143,080		132	Bartlesville	2,350	150	Sandstone
Scott 19-23-9E	Jan. 1925	2,500	114,245		73	Bartlesville	2,525	75	Sandstone
Seeley-Wick 22-22-11E	Jan. 1922	7,000	268,640		329	Bartlesville	1,930	45	Sandstone
Smith-Jobe (near-Blackwell) 10-24-13E	Sept. 1938					Mis. lime	1,662	3	Lime
Teeter 36-22-9E	Jan. 1922	4,000	220,460		207	Bartlesville	2,400	150	Sandstone
Teichgraber 2-25-8E		900	22,265		22	Bartlesville	2,450		Sandstone
Thrall 28-23-10E	1921	7,000	155,125		255	Bartlesville	2,190	166	Sandstone
Virgil 13-24-12E	Jan. 1916	4,800	123,370		130	Bartlesville Burgess Mis. lime	1,550 1,700 1,700	 10 	Sandstone Conglomerate Lime
Virgil North 3-23-13E		8,000	454,060		294	Bartlesville Mis. lime	1,550 1,700		Sandstone Lime
Wiggins 7-24-11E	Jan. 1925	2,500	52,560		46	Bartlesville	1,860	15	Sandstone
Wilkerson 6-25-9E		1,300	16,060		14	Bartlesville	2,300		Sandstone
Willard 7-27-11E		1,000	14,965		3				
Harvey County			921,770	19,047,417	131				
Halstead 36-22-2W	April 1929	1,200	175,480	1,044,186	20	Chat	3,005	30	IR
Hesston now included with Graber, McPherson Co									
Hollow-Nikkel 30-22-3W	Dec. 1931	1,500	682,790	17,755,207	104	Lans. K. C. Chat Hunton Wilcox Arbuckle	2,499 3,195 3,507 3,500 	21 13 2 14 	Lime IR Lime Sandstone Dolomite
Sperling 23-22-2W	Jan. 1935	500	63,500	248,024	7	Hunton Wilcox	3,279 3,447	66 16	Lime Sandstone
Kingman County									
Cunningham 30-27-10W	Jan. 1931	1,400	253,985	1,917,533	40	Lans. K. C. Viola Wilcox Arbuckle	3,390 3,925 4,055 4,094	74 33 39 15	Lime Lime Sandstone Dolomite
Kingman abandoned									
Sheperd shut in									
Marion County			377,330		151				
Covert-Sellers 1-21-4E	Sept. 1920	2,400	33,945		18	Viola	2,330	5	Lime
Florence 20-21-5E	Dec. 1929	3,000	45,000		19	Viola	2,300	10	Lime
Hillsboro 12-19-2E	Oct. 1927	300	59,495	1,707,084	13	Viola	2,800		Lime
Lost Springs 22-17-4E	Sept. 1926	2,400	206,400		61	Chat	2,365		IR
Peabody 5-22-4E	Sept. 1929	3,000	32,485		40	Viola	2,532		Lime
McPherson County			3,754,538	63,352,120	599				
Bornholdt 30-20-5W	Aug. 1937	640	64,288	74,936	16	Chat	3,292	43	IR
Bornholdt North 18-20-5W	Dec. 1939	40			1	Chat	3,304	38	IR
Canton North 26-18-1W	July 1936	40	17,090	50,768	1	Chat	2,803	29	IR
Chindberg 18-19-2W	Jan. 1929	700	118,965	1,126,460	6 25	Lans. K. C. Chat	2,363 3,007		Lime IR

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Graber (includes Hesston) 32-21-1W	May 1934	2,800	1,059,645	4,191,978	3 2 121 1	Chat Misener Hunton Wilcox	 3,323 3,274 3,398	 3 24 8	IR Sandstone Lime Sandstone
Johnson 35-19-3W	Feb. 1932	1,200	94,215	2,456,565	15	Chat	3,032	14	IR
Lindsborg 8-17-3W	Jan. 1938	160	13,675	17,732	2	Viola	3,352	21	Limestone
McPherson 29-18-2W	Sept. 1926	2,000	29,380	802,485	29	Lans. K. C. Chat Viola	2,340 2,967 3,140	55 11 60	Lime IR Limestone
Ritz-Canton 1-20-2W	July 1929	13,000	1,726,150	32,186,873	265	Lans. K. C. Chat Viola Wilcox	2,360 2,935 3,412 3,440	39 31 2 4	Lime IR Limestone Sandstone
Roxbury 18-17-1W	Nov. 1938	250	58,690	59,255	6	Chat	2,684	5	IR
Voshell 9-21-3W	Aug. 1929	3,500	572,440	22,385,068	105	Chat Viola Wilcox Arbuckle	3,095 3,301 3,322 3,394	13 3 3 10	IR Limestone Sandstone Dolomite
Ness County									
Aldrich 7-18-25W	Oct. 1929	2,000	62,315	118,156	11	Ft. Scott Mis. lime	4,378 4,428	21 2	Lime Lime
Norton County									
Van Patten 26-4-21W	May 1939	40			1	Lans. K. C.	3,475	21	Lime
Pawnee County									
Pawnee Rock 13-20-16W	Sept. 1936	640	43,695	81,762	6	Arbuckle	3,825	16	Dolomite
Phillips County									
Bow Creek 25-5-18W	May 1939	40	3,525	3,525	1	Lans. K. C.	3,111	53	Lime
Pratt County			23,963	43,686	4				
Cairo 7-28-11W	Dec. 1939	40	218	218	1	Viola	4,267	16	Lime
Iuka 11-27-13W	Aug. 1937	160	23,745	43,468	3	Simpson	4,292	7	Dolomite
Reno County			3,869,652	31,929,293	528				
Abbyville 24-24-8W	Jan. 1927	1,200	27,705	346,978	4	Lans. K. C.	3,540	9	Lime
Buhler 25-22-5W	Apr. 1938	500	188,240	222,359	1 10	Viola Simpson	3,890 3,897	19 5	Lime Sandstone
Burrton 23-23-4W	Feb. 1931	5,000	3,099,000	27,962,307	346 92 1 2	Chat Hunton Wilcox Arbuckle	3,266 3,583 3,723 3,775	42 6 4 9	IR Lime Sandstone Dolomite
Hilger 16-26-4W	Mar. 1934	600	250,600	1,509,459	33	Viola	4,062	5	Lime
Lerado 11-26-9W	Dec. 1935	1,800	295,255	1,825,670	1 32	Lans. K. C. Viola	3,535 4,128	4 28	Lime Lime
Yoder 34-24-5W	Oct. 1935	500	8,852	62,520	6	Chat	3,450	51	IR
Rice County			6,824,105	46,548,219	741				
Brandenstein 10-19-10W	Nov. 1933	160	17,430	343,851	2	Lans. K. C.	3,014	12	Lime
Bredfeldt 7-18-9W	Apr. 1937	40	3,280	12,446	1	Arbuckle	3,223	17	Dolomite
Bredfeldt West 12-18-10W	Dec. 1939	40			1	Arbuckle	3,260	8	Dolomite
Campbell 28-19-9W	Jan. 1938	800	416,750	438,650	19	Arbuckle	3,195	13	Dolomite
Chase 32-19-9W	Mar. 1931	4,800	1,651,564	18,689,991	4 133	Lans. K. C. Arbuckle	2,942 3,246	12 38	Lime Dolomite
Cramm joined to Chase Jan. 1940									
Cramm North joined Cramm Mar. 1939									
Doran 13-19-10W	Sept. 1936	160	15,050	90,714	2	Arbuckle	3,291	20	Dolomite

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Edwards............ 3-18-8W	Jan. 1936	2,000	536,280	1,610,998	54	Arbuckle	3,278	5	Dolomite
Geneseo............ 25-18-8W	May 1934	4,600	1,226,375	3,765,599	143	Arbuckle	3,132	40	Dolomite
Guldner............ 16-18-9W	July 1935	160	10,465	223,639	3	Lans. K. C. Arbuckle	2,884 3,227	141 3	Lime Dolomite
Habiger joined to Bloomer May 1939									
Haferman.......... 6-19-9W	June 1936	700	62,045	339,938	9	Arbuckle	3,192	24	Dolomite
Heins.............. 8-18-10W	July 1938 Sept. 1938	80	11,240	17,142	1	Lans. K. C. Arbuckle	3,000 3,254	19 14	Lime Dolomite
Keesling............ 10-20-9W	Apr. 1935	700	293,375	2,337,461	43	Arbuckle	3,239	26	Dolomite
Lyons.............. 14-20-8W	Nov. 1939	40	887	887	1	Simpson	3,280	4	Sandstone
Midway............ 8-20-9W	Apr. 1939	240	35,689	35,689	6	Arbuckle	3,244	19	Dolomite
Orth............... 27-18-10W	July 1932	1,000	73,585	580,762	2 11	Lans. K. C. Pre-Cambrian	2,915 3,240	21 3	Lime Quartzite
Ploog.............. 33-18-9W	June 1930	300	83,230	1,097,270	10	Arbuckle	3,252	19	Dolomite
Ponce.............. 28-21-7W	Apr. 1936	40	5,456	20,497	1	Sooy	3,388	40	Conglomerate
Proffitt............. 12-20-10	Dec. 1938	40	1,553	1,553	1	Arbuckle	3,227	8	Dolomite
Raymond.......... 21-20-10W	June 1929	1,000	230,140	5,522,353	4 28	Lans. K. C. Arbuckle	3,130 3,330	10 21	Lime Dolomite
Rickard............. 22-18-9W	Oct. 1935	40	6,780	44,710	1	Wilcox Arbuckle	3,285 3,324	20 41	Sandstone Dolomite
Silica See Barton Co.									
Soeken joined to Chase Jan. 1940...									
Stumps............. 4-18-10W	May 1935	1,200	170,597	662,210	25	Arbuckle	3,229	38	Dolomite
Welch............... 2-21-6W	Apr. 1924	1,500	129,900	4,087,020	28	Chat	3,370	44	IR
Welch North........ 23-20-6W	June 1937	160	8,870	30,131	3	Chat	3,334	32	IR
Wenke.............. 7-20-10W	Mar. 1935	300	50,985	209,422	7	Arbuckle	3,360	13	Dolomite
Wenke West......... 18-20-10W	Oct. 1938	80	10,280	10,656	2	Arbuckle	3,292	5	Dolomite
Wherry............. 11-21-7W	Sept. 1933	7,200	1,260,887	5,367,561	193	Sooy	3,358	22	Conglomerate
Wherry East........ 12-21-7W	Sept. 1937	160	19,799	52,128	3	Sooy	3,455	14	Conglomerate
Rooks County............			262,370	824,984	36				
Dopita.............. 31-8-17W	Apr. 1934	160	36,970	77,020	1 4	Lans. K. C. Arbuckle	3,212 3,409	5 10	Lime Dolomite
Faubin............. 12-6-18W	Feb. 1936	80	7,210	33,100	2	Lans. K. C.	3,128	22	Lime
Kruse.............. 3-10-16W	Jan. 1928	40	1,600	10,211	1	Lans. K. C.	3,115	6	Lime
Laton.............. 11-9-16W	July 1927	400	105,720	353,046	13	Lans. K. C.	3,228	33	Lime
Nyra abandoned.....									
Stockton........... 26-7-17W	Apr. 1937	160	6,880	22,695	2	Lans. K. C.	3,118	62	Lime
Westhusin.......... 11-9-17W	Nov. 1936	400	85,990	238,213	9	Lans. K. C.	3,231	11	Lime
Zurich.............. 26-10-19W	Sept. 1934	200	18,000	90,699	4	Lans. K. C.	3,340	9	Lime
Rush County............			451,815	1,150,856	21				
Otis................. 10-18-16W	July 1934	600	445,390	1,108,527	17	Reagan	3,527	9	Sandstone
Winget............. 15-16-16W	Dec. 1936	80	6,425	42,329	3 1	Lans. K. C. Arbuckle	3,243 3,537	4 8	Lime Dolomite
Russell County...........			10,298,012	55,577,530	1,410				
Allon joined to Gurney May 1939.....									

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Anschutz 10-15-13W	Apr. 1936	80	23,250	85,637	2	Arbuckle	3,311	16	Dolomite
Atherton (now includes Balta and Balta N.) 30-13-14W	July 1935	1,800	197,189	604,214	9	Lans. K. C.	3,008	47	Lime
					33	Arbuckle	3,284	5	Dolomite
Atherton North 18-13-14W	June 1939	40	2,119	2,119	1	Arbuckle	3,130	3	Dolomite
Balta joined to Atherton Jan. 1940									
Balta North Joined to Atherton Jan. 1940									
Benso joined to Gorham Jan. 1940									
Big Creek 36-14-15W	July 1935	900	255,620	1,224,783	2	Lans. K. C.	2,908	42	Lime
					24	Gorham	3,152	5	
					4	Arbuckle	3,171	5	Dolomite
Big Creek East 31-14-14W	July 1938	80	15,875	20,107	1	Lans. K. C.	3,180		Lime
					2	Arbuckle	3,149	4	Dolomite
Boxberger 36-15-15W	Dec. 1935	160	12,677	116,200	4	Lans. K. C.	3,147	4	Lime
Bunker Hill 31-13-12W	Oct. 1935	160	10,445	53,912	3	Lans. K. C.	2,965	16	Lime
Coralena joined to Trapp Sept, 1939									
Coralena East joined to Coralena March 1939									
Coralena South joined to Coralena May 1939									
Donovan 10-15-15W	Feb. 1935	40	6,665	26,676	1	Lans. K. C.	3,193	7	Lime
Dubuque 34-15-12W	Oct. 1935	160	14,153	130,377	2	Arbuckle	3,275	3	Dolomite
Eichman 34-15-13W	May 1935	800	39,730	578,315	6	Arbuckle	3,316	10	Dolomite
Fairfield 22-15-13W	Dec. 1938	40	3,831	3,831	1	Arbuckle	3,352	25	Dolomite
Fairfield North 16-15-13W	Jan. 1939	80	34,218	34,218	2	Lans. K. C.	3,112		Lime
					2	Arbuckle	3,332	2	Dolomite
Fairport 8-12-15W	Nov. 1923	3,600	648,290	13,812,764	145	Lans. K. C.	2,950	12	Lime
						Gorham	3,211	6	
Foster 19-15-15W	May 1938	40	5,550	10,570	1	Lans. K. C.	3,114	2	Lime
Gideon 8-15-14W	June 1930					Sooy	3,266	7	Conglomerate
Gorham (includes Dumler, Milberger, Peterson, and Sullivan) 5-14-15W	Oct. 1926	6,000	2,126,470	14,849,948	1	Tarkio	2,525	25	Lime
					9	Topeka	2,765	105	Lime
					140	Lans. K. C.	3,027	30	Lime
					2	Arbuckle	3,289	4	Dolomite
					131	Gorham	3,299	1	Sandstone
Green Vale 4-15-12W	Apr. 1938	200	53,465	65,212	7	Lans. K. C.	3,040	5	Lime
					1	Arbuckle	3,267	21	Dolomite
Gurney 23-14-14W	Mar. 1935	2,000	639,655	1,371,048	3	Topeka	2,675		Lime
					61	Lans. K. C.	3,001	5	Lime
					9	Gorham	3,165	3	Sandstone
					2	Pre-Cam.	3,275	5	Granite
Gurney South joined to Gurney Sept. 1939									
Hall (includes Letsch and Letsch S.) 30-14-13W	Oct. 1931	2,000	1,234,481	2,395,522	110	Lans. K. C.	2,985	100	Lime
					12	Reagan	3,129	1	Sandstone
					1	Arbuckle	3,451	3	Dolomite
					1	Pre-Cam.	3,156	25	Granite
Hall North merged with Hall, 1938									
Karst 27-15-14W	Oct. 1935	160	26,155	145,350	4	Arbuckle	3,315	4	Dolomite
Letsch joined to Hall Aug. 1939									

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Letsch South joined to Hall Jan. 1940.....									
Michel joined to Gurney Sept. 1939....									
Neidenthal.......... 23-14-15W	Aug. 1934	600	69,440	794,848	10	Arbuckle	3,246	4	Dolomite
Russell............ 22-13-14W	Feb. 1934	1,200	360,880	4,032,396	3 46	Lans. K. C. Arbuckle	3,195 3,280	9 6	Lime Dolomite
Schneider joined to Trapp Dec. 1939...									
Sellens.............. 26-15-13W	July 1929	1.200	201,845	2,205,973	28	Lans. K. C. Arbuckle	3,088 3,352	9 13	Lime Dolomite
Smoky Hill.......... 2-15-14W	Feb. 1938	80	11,268	21,601	2	Lans. K. C.	2,950	9	Lime
Steinert............. 21-15-15W	Mar. 1936	40	5,160	31,892	1	Lans. K. C.	3,060	36	Lime
Trapp (now includes Coralena and Schneider)........ 23-15-14W	Oct. 1939	17,920	4,083,741	13,013,806	2 46 1 500	Topeka Lans. K. C. Sooy Arbuckle	2,889 3,062 3,252	7 2 1	Lime Lime Conglomerate Dolomite
Trapp West......... 15-15-14W	July 1939	160	9,648	9,648	3	Arbuckle	3,249	7	Dolomite
Vaugh............... 17-14-14W	Apr. 1937	1,000	208,555	567,831	21 2 4	Lans. K. C. Gorham Arbuckle	3,004 3,282 	30 7 	Lime Sandstone Dolomite
Williamson......... 9-14-14W	Feb. 1936	160	8,905	38,623	2	Tarkio	2,522	28	Lime
Scott County............									
Shallow Water....... 15-20-33W	Dec. 1934	600	257,460	749,962	8	Mis. lime	4,670	16	Lime
Sedgwick County.........			1,203,433	38,685,952					
Andover South...... 36-27-2E	Nov. 1937	80	4,308	15,372	1	Wilcox	3,098	1	Sandstone
Bentley............. 19-25-1W	Apr. 1934					Lans. K. C.	2,911		Lime
Cross............... 27-25-1W	Apr. 1929	160	3,910	66,210	2	Lans. K. C.	2,690	40	Lime
Eastborough......... 19-29-2E	Aug. 1929	1,000	223,745	7,691,661	47	Chat Viola	2,956 3,238	14 4	IR Lime
Eastborough North.. 8-27-2E	Aug. 1938	80	3,881	3,881	2	Viola	3,258	4	Lime
Goodrich............ 16-25-1E	Dec. 1928	640	266,300	2,413,200	34	Lans. K. C. Chat Misener	2,614 3,010 3,334	2 10 3	Lime IR Lime
Greenwich.......... 14-26-2E	May 1929	700	255,500	6,036,162	43	Chat Viola Wilcox	2,865 3,321 	3 5 	 Lime Sandstone
Kyuske............. 24-25-1E	Jan. 1929	40	2,460	135,340	1	Burgess	3,489	2	Sandstone
Oatville............. 18-28-1E	Nov. 1937	40	3,154	8,370	1	Wilcox	3,489	2	Sandstone
Robbins............ 20-28-1E	June 1929	420	117,680	2,777,847	51	Chat	3,090	12	Lime
Valley Center....... 1-26-1W	Aug. 1928	1,500	322,495	19,537,909	70	Misener Lans. K. C. Viola	3,368 2,579 3,366	7 13 2	Lime Lime Lime
Stafford County..........			2,328,482	6,834,921	306				
Bonham............ 28-25-12W	Apr. 1938					Arbuckle	4,210	10	Dolomite
Drach.............. 12-22-13W	Nov. 1937	800	70,345	139,178	9	Arbuckle	3,693	12	Dolomite
Fischer............. 31-21-12W	May 1938	120	30,775	37,714	5	Arbuckle	3,641	7	Dolomite
Gates............... 27-21-13W	May 1933	640	98,090	489,118	11	Arbuckle	3,679	39	Dolomite
Jordan.............. 15-25-14W	Nov. 1936	160	33,740	130,427	4	Lans. K. C.	3,722	5	Lime
Kipp................ 27-25-14W	Jan. 1937	80	17,685	57,601	2	Lans. K. C.	3,827	79	Lime
Leesburgh.......... 12-25-13W	Apr. 1938	300		26,832	7	Arbuckle	4,153	10	Dolomite

In McPherson County a great deal of excitement was created by the finding of important quantities of oil in the "Chat" horizon. The Bornholdt pool, which was discovered in August 1937, was neglected during the year 1938, but during 1939 a revival of drilling brought the total number of wells to 14 and also resulted in the discovery of a new pool called Bornholdt North. The only other pool in the county that received important attention was the Roxbury, where the five additional wells

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Wells Producing	Producing Horizon			
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Max 35-21-12W	Aug. 1938	80	17,056	17,533	1 2	Lans. K. C. Arbuckle	3,356 3,570	16 5	Lime Dolomite
Mueller 29-21-12W	Mar. 1938	80	41,078	71,970	2	Arbuckle	3,594	7	Dolomite
Rattlesnake 13-24-14W	Oct. 1938	40	8,710	11,089	1	Lans. K. C.	3,608	48	Lime
Richardson 36-22-12W	Oct. 1930	1,200	450,720	3,365,966	59	Arbuckle	3,537	62	Dolomite
St. John 23-24-13W	Apr. 1935	1,200	158,200	527,128	19	Lans. K. C. Arbuckle	3,588 4,075	32 12	Lime Dolomite
Sittner 33-21-12W	Aug. 1937	600	91,270	174,931	2 4	Lans. K. C. Arbuckle	3,278 3,600	136 6	Lime Dolomite
Sittner South 3-22-12W	May 1938	240	26,125	31,669	6	Arbuckle	3,594	6	Dolomite
Snider 3-21-11W	Apr. 1936	320	19,256	141,770	1 3	Simpson Arbuckle	3,362 3,324	6 18	Sandstone Dolomite
Snider South 16-21-11W	Aug. 1938	80	9,730	12,429	2	Arbuckle	3,402	7	Dolomite
Zenith 23-24-11W	Sept. 1937	4,000	1,296,780	1,671,536	167	Misener	3,804	20	Sandstone
Sumner County			1,380,625	39,986,987	276				
Anness 2-30-4E	Oct. 1937	40	6,700	29,298	1	Wilcox	4,394	7	Sandstone
Caldwell 17-35-3W	May 1929	160	58,400	1,276,200	4	Wilcox	4,765	19	Sandstone
Churchill 25-31-2E	July 1926	1,000	195,965	18,143,957	69	Stalnaker	1,820	25	Sandstone
Latta 9-30-2W	June 1927	200	1,775	42,232	12	Lans. K. C. Lans. K. C.	3,042 3,200	14 10	Lime Lime
Oxford 23-32-2E	Aug. 1927	800	299,140	14,033,175	13 6 40	Stalnaker Layton Arbuckle	2,020 2,890	 3	Sandstone Sandstone Dolomite
Oxford West 17-32-2E	May 1926	160	16,375	475,874	3	Arbuckle			Dolomite
Padgett 23-34-2E	Oct. 1924	1,800	81,395	1,770,638	20	Chat	3,474	28	IR
Rainbow Bend West 24-33-2E		160	5,840		3	Burbank Arbuckle			Sandstone Dolomite
Rutter 21-33-2E	July 1926	40	12,650	39,241	1	Chat	3,315		IR
Vernon North 15-35-2E	July 1915	200	36,585	182,466	5	Chat	3,443	22	IR
Wellington 33-31-1W	Dec. 1929	1,200	664,540	3,989,202	99	Chat	3,655	11	IR
Zyba 7-30-1E	Nov. 1937	40	1,260	4,704	1	Wilcox	3,866	3	Sandstone
Trego County			43,380	548,580	13				
Gugler 36-12-21W	Dec. 1936	40	4,380	14,188	1	Arbuckle	3,830	8	Dolomite
Wakeeney 14-11-23W	Oct. 1934		39,000	340,670	12	Lans. K. C.	3,619	8	Lime
Woodson County			276,305						
Big Sandy 14-26-14E			12,045		20				
Hoagland 2-24-14E			18,980		16				
Wiede 32-23-15E			10,585		12				
Winterscheid 15-23-14E		7,700	234,695		225	Mis. lime	1,575	65	Lime

TABLE 2.—*List of Producing Gas Fields*

Field and Location	Discovery Date	Area, Acres	Production, Thousand Cu. Ft.		Wells Producing	Producing Formation			Character
			In 1939	Cumulative		Name	To Top, Ft.	Thickness, Ft.	
Barber County									
Medicine Lodge 13-33-13W	Jan. 1927	5,000	6,380,558	36,437,112	32	Chat	4,455	10	Insol. res.
Barton County									
Albert—See Otis in Rush County									
Prusa North 17-16-11W	Feb. 1939	160	7,701	7,701	1	Lans. K. C.	3,133	9	Lime
Clark County									
Morrison 21-32-21W	Nov. 1928	160			1	Sooy	5,443	32	Conglomerate
Edwards County									
McCarty 31-25-17W	May 1929	40	53,792		1	Sooy	4,545	10	Conglomerate
Ford County									
Pleasant Valley 34-27-21W	July 1938	160			1	Mis. lime	4,922 4,890 4,895	 20 3	Lime Lime Lime
Harvey County									
Hollow 30-22-3W	Dec. 1931	1,600	189,736			Chat	3,195		Insol. res.
Sperling 23-22-2W	Jan. 1935	600	65,878	6,196,878	2	Chat	2,955	50	Insol. res.
Haskell County									
Satanta Gas (see Hugoton)									
Kingman County									
Cunningham 30-27-10W	(Included with Cairo in Pratt County					Cottonwood Wabaunsee Viola Simpson Arbuckle	1,993 2,475 3,922 4,003 4,109	57 10 36 52 75	Lime Sandstone Lime Sandstone Dolomite
McPherson County			6,516,578[1]						
Moundridge 12-21-2W	Mar. 1938	160			1	Mis. lime	3,007	9	Lime
Pratt County									
Cairo 7-28-11W	Nov. 1935	12,000	2,453,079	8,525,362	27	Viola	4,278	8	Lime
Reno County			7,438,314						
Burrton 23-23-4W	Sept. 1930	5,000	6,387,118	36,923,118	52	Chat	3,298	70	Insol. res.
Yoder 34-24-5W	Oct. 1934	800	861,461		4	Chat	3,402	50	Insol. res.
Rice County									
Guldner 16-18-9W	June 1935	160				Lansing	2,884	10	Lime
Lyons 34-19-8W	July 1888	1,500	2,838,722	5,051,284	1 8	Simpson Arbuckle	3,290 3,277	7 3	Dolomite Dolomite
Orth 27-18-10W	July 1933	640	460,465		3	Lans. K. C.	2,906	30	Lime
Thurber 22-21-9W	Oct. 1937	160	769,577	1,195,782	3	Misener	3,317	10	Conglomerate
Rush County									
Otis 11-18-16W	Mar. 1930	15,000	8,062,919	44,426,000	57	Reagan	3,507	2	Sandstone
Sedgwick County									
Derby 32-28-2E	Aug. 1937	160	648,758	733,758	1	Stalnaker	2,215	17	Sandstone
Sherman County									
Goodland 30-8-39W	March 1939	640			2	Smoky Hill			Chalk
Sumner County									
Padgett 23-34-2E	Oct. 1924	1,200	166,262						
Wellington 33-31-1W	Dec. 1929	1,200	828,063		97	Chat	3,655	12	Insol. res.
Various Counties Southwest Kansas									
Hugoton 3-35-34W	1922	2 million	28,964,493	188,964,000	283	Winfield Ft. Riley Florence	2,755 2,800 2,850	10 8 10	Lime Lime Lime

[1] Total for McPherson County includes Canton, Graber, McPherson, and Voshell pools.

drilled have brought the total up to 6. In Reno County the Buhler pool now has 10 wells as compared to 2 for the previous year. A new producing horizon was discovered when one of the old wells was plugged back to the Viola limestone and made a successful commercial well at that level. In Rice County four pools were actively developed during the year. The Campbell pool now has 19 wells as compared to 3; Geneseo now has 142 wells as compared to 103; and the Wherry pool has 191 wells as compared to 165 for the preceding year. A most interesting development was a well drilled over a mile east of the Orth pool, which was found productive in the pre-Cambrian quartzite. Later an offset well was drilled and the two wells were added to the Orth pool.

TABLE 3.—*Data on New Pools Found during* 1939

County and Pool	Location	Discovery Well	Potential, Bbl.	Producing Horizon and Depth
Barton County				
Feltes	14-16-12 W	Day No. 1 Feltes	50	Sooy 3342-44
Harzman	33-16-11 W	Republic No. 1 Harzman	25	Lans. K. C. 3124-32
Kreier	30-16-11 W	B. B. & M. No. 1 Kreier	100	Sooy 3130-35
Kruckenberg	14-19-15 W	Amerada No. 1 Kruckenberg	130	Arbuckle 3580-85
Pospishel	20-17-15 W	Republic No. 1 Pospishel	230	Arbuckle 3548-50
Prusa North	17-16-11 W	Sinclair No. 1 Oeser	100	Lans. K. C. 3133-42
Prusa West	18-16-11 W	Vernon No. 1 Hoffman	525	Lans. K. C. 3207-17
McPherson County				
Bornholdt North	18-20- 5 W	Springrose No. 1 Swanson	2,500	Chat 3304-46
Norton County				
Van Patten	26-4-21 W	Power No. 1 Van Patten	200	Lans. K. C. 3475-82 and 3487-96
Phillips County				
Bow Creek	25-5-18 W	Blue Stem No. 1 Donaldson	825	Lans. K. C. 3111-15
Pratt County				
Cairo	7-28-11 W	Skelly No. 1 Harding	375	Viola 4267-83
Rice County				
Bredfeldt West	12-18-10 W	Saco No. 1 Habiger	250	Arbuckle 3265-68
Midway	8-20-9 W	Phillips No. 1 Proffitt	210	Arbuckle 3260-63
Russell County				
Atherton North	18-13-14 W	Cities Serv. No. 1 Dutt	250	Arbuckle 3130-33
Fairfield North	16-15-13 W	Wakefield No. 1 Meharg	840	Lans. K. C. 3112-20 Arbuckle 3232-39
Trapp West	15-15-14 W	Phillips No. 1 Maier	275	Arbuckle 3250-56
Butler County				
Ferrell	28-28-8 E	Table Mesa No. 1 Farrell	50	Chat 2647-89
Cowley County				
Darien	33-30-4 E	Hartman Blair No. 1 A Brown	600	Arbuckle 3286-87
Rahn	13-34-5 E	Garden No. 1 Rahn	1,035	Bartlesville 2915-45
Johnson County				
Gardner	20-14-22 E	Sagamore No. 1 Metropolitan Life	25	Bartlesville 902-910

In Rooks County the only pool that received much attention was the Laton pool, where the total number of wells was doubled over the preceding year. In Russell County five pools were actively developed. The Atherton pool now has 16 wells as compared to 10, the Gurney pool has 52 as compared to 15, and the Hall pool has 119, as compared to 55 for the preceding year. The Coralena pool was united to the Coralena East and the Coralena North pools during the early part of the year and these three pools were united with the Trapp pool toward the close of the year. This rearrangement of pool areas makes the Trapp pool the third largest pool in Kansas with an area of 17,920 acres and a total of 553 wells. The only larger pools found in Kansas are the El Dorado and Silica. In Stafford County important extensions were found to five pools: The Drach pool now has 9 wells as compared to 1; the Leesburgh has 7 as compared to 1; the Sittner South pool has 6 as compared to 1 and the Zenith has 162 wells as compared to 97 at the close of the previous year. The Max pool has a new producing horizon in the Lansing-Kansas City limestone. In Sumner County the most important extension was recorded in the Latta pool, which now has 12 wells. The large Wellington pool of that county added only two wells during the year.

New Counties.—During the year 1939 three new counties joined the producing column. One of these is Norton County, in the northwest part of the state, where the No. 1 Van Patten well drilled by the Power Oil Co. encountered a production of 200 bbl. of oil in the Lansing-Kansas City limestone in two different zones of porosity. The second county is Phillips, in the northern part of the state. There the Blue Stem No. 1 Donaldson found commercial production at a depth of 3111 ft. in the Lansing-Kansas City limestone. The potential production of the well is over 800 bbl. The name of the new pool is Bow Creek. The third county is Sherman, in the far western part of Kansas. In this county gas was found in the Smoky Hill chalk at a depth of approximately 1100 ft. Whereas the daily production is not large, it does indicate a possible large gas field in this part of Kansas.

Important Wildcats.—During the year, 163 wildcats were drilled in western Kansas and 42 in eastern Kansas. Of these 76 found oil in western Kansas and 5 found new oil pools in eastern Kansas. Six new gas areas were opened in western Kansas. Of the remaining wells, 81 are dry holes in western Kansas and 37 are dry holes in eastern Kansas. Among the dry wildcats completed during the year, the large majority were drilled by independent operators. In many cases the acreage was farmed out to them by the large oil companies. Most of these wells penetrated all producing horizons down to and including the Arbuckle limestone. It is also interesting to note that many of these wildcats were drilled because the acreage involved was about to expire. About one fourth of them were drilled on the basis of subsurface information. A smaller number were drilled on the basis of core-drill information and only about 6 per cent were drilled on the basis of seismograph information. Approximately 33 per cent were drilled without any of the usual geological prerequisites.

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Oil and Gas Development in Kentucky during 1939

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(New York Meeting, February 1940)

Activity in the oil fields of the state was at a low ebb during the year because of the longest period of low prices that has yet prevailed, which has been detrimental to both the eastern and western sections of the state.

Production for the state as a whole shows a drop of 209,192 bbl. during 1939, the total being 5,356,963 bbl. The loss is in the production of the western division, where a loss of approximately 300,000 bbl. more than offset a gain of approximately 100,000 bbl. in the eastern division. The loss in the western division can be attributed to decline in drilling activity due to the low prices prevailing, which were caused by flooding of the normal markets with cheap Illinois crude. The gain in the eastern division is the result of repressuring operations begun in previous years and now showing results, and not to any renewed drilling activity.

Gas development in western Kentucky during 1939 was of minor importance. In eastern Kentucky approximately 50 producing gas wells were drilled, which were sufficient for present market with excess reserves already developed. With the severe winter and additional industry load every gas well connected has been on line for the past three months. Although all demands are being met, development will be greatly increased during 1940 to meet depletion.

From the geological point of view, the drilling activity in the western division developed additional information of benefit. Several wells on blocks of acreage assembled in previous years were drilled in the deeper parts of the Western Coal Basin—southern part of the Illinois Basin—giving for the first time accurate information about the Pennsylvanian and lower formations down to and through the Devonian.

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TABLE 1.—*Oil and Gas Production in Eastern Kentucky*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Bowling Green, *Allen-Warren-Simpson*	1918			12,550,856	150,856
2	Barren (abandoned in 1920), *Barren*	1919	3,667		2,609,879	34,850
3	Olympia (abandoned), *Bath*	1919				
4	Ragland, *Bath, Rowan*	1903			3,*xxx*,*xxx*	
5	Red Bird gas, *Bell*	1930		600		
6	Boyd Co. and Ashland, *Boyd*	1924		16,640		
7	Big "6" gas, *Breathitt*	1921		16,000		
8	Breslin, *Butler*	1938	40		200	200
9	Harper, *Butler*	1938	100		4,*xxx*	1,*xxx*
10	Huntsville, *Butler*	1938	*x*	*x*	3*xx*	1*xx*
11	Rochester, *Butler*	1938	100		10,*xxx*	4,*xxx*
12	Silver City, *Butler*	1938	250		18,*xxx*	
13	Oneida-Burning Springs, *Clay*	1925		7,000		
14	Burning Springs gas, *Clay*	1909				
15	Morton's Gap, *Hopkins*	1920	50		*x*	*x*
16	Logsdon Valley, LeGrande, Bonnieville, *Hart*	1930	2,9*yy*		6,1*xx*,*xxx*	87,048
17	Birk City, *Henderson-Daviess*	1938	1,200		740,382	
18	Gilmore pool, *Henderson*	1938	150			
19	Isonville, *Elliott*	1917	100	2,000	88,994	2,003
20	Irvine, *Estill*	1916	4,7*xx*		14,*xxx*,*xxx*	18*x*,*xxx*
21	Ross Creek, *Estill*	1919	468		830,720	25,553
22	Wagesville, *Estill*	1918	400		456,522	6,395
23	Floyd gas field, *Floyd*	1904	[1]	332,300		
24	Big Sandy oil field, *Floyd, Knott*	1918	160		249,*xxx*	31,089
25	Carlisle gas, *Gallatin, Carroll*	1932				
26	Niagara, *Henderson*	1930	218			
27	Spottsville, *Henderson*	1938	60		*x*,*xxx*	
28	Wayne, *Wayne, McCreary*	1898	8,5*xx*		4,5*xx*,*xxx*	35,112
29	Sebree, *Webster*	1938			600	600
30	Ambrose-Weller, *Ohio*	1925	600		4,278,*xxx*	152,*xxx*
31	Buford, *Ohio*	1928	346		1,85*x*,*xxx*	15*x*,*xxx*
32	Herbert, *Ohio*	1920	350		452,000	12,000
33	Flat Gap gas, *Johnson*	1919		10,880		
34	Blaine, *Johnson, Lawrence*	1919	6,820		16,000,404	456,518
35	Oil Springs, *Johnson, Magoffin*	1920	6,100		9,525,006	269,208
36	Elna, *Johnson*	1921			1,634,705	41,540
37	Swamp Br. gas, *Johnson*	1929	3	3,000	Not marketed	
38	Win gas, *Johnson*			1,980		
39	Knott County, *Knott*	1906	[1]	115,440		
40	Indian Creek gas, *Knox*	1929		1,200		
41	Little Richland, *Knox*		(Abandoned)			

[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] See Beaver Creek.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.			Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Repressuring Operation^d	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
1			2,0xx				1,xxx			1,xxx					
2															
3			20				0								
4			1xx				0								
5			3			3		0							
6	y	y	216		1xx			8x							
7	y	y	14	14	10	1		3							
8			1	1			1				x			36	
9			14	14	0		14	0							
10			6				1			1	x				
11			12				12			12	x			39	x
12			23	0	0		12	0		23				36	x
13	y	y	32			26		28			305				
14	y	y	5					5							
15			x	x	x	1	5								
16				x	x	1,2xx	1,2xx	2xx		1,2xx					
17			102	39	0	0	63			63	x	x		38	x
18			7	1	0	0	7			7	x	x		38	x
19			34				26	8		8					
20			1,1xx				1,0xx			1,0xx			SR		
21			18x	[2]			8x			8x			SR		
22			150				3x			3x			SR		
23	y	y	1,280	14	2x			1,1xx							
24						6	51			47					
25								17			160	20			
26			63	x	0		63			63				34	
27			5	2	0	0	5		2	1	x	x		39	
28			1,4yy							6xx					
29			1	0			1	0		1	600			35.5	
30			190	0			190			190				36	
31			125	0	0		125							35.5	
32			129	0	0	0	129	0		99		x		34	
33	y	y	2xx	0	2x	1xx		7x							
34			1,118	[2]			1,118			1,118			SR	36	
35			1,055				1,033			1,033			SR	37	
36			250				230			230			SR	36	
37	y	y	22	0	0	22	3	19							
38	y	y	28		2x			6							
39	y	y	248	22	4	0		244							
40	y	y	8								(See Pet. x)				
41															

[2] Pressure.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Shallow sand, Corniferous deep sand	Mis, Dev	L, S	Por			15±	D, T, A, MC	Ord	*x*
2	Second sand, Corniferous, Trenton, Amber oil sand	Mis, Dev, Sil, Ord	L, S	Por				MC, T, D, N	Ord	*x*
3	Silurian		L	Cav					Ord	
4	Corniferous	Dev	LS	Por	300–500	325–525	25	SC	Ord	
5	Big Lime, Brown shale, Corniferous	Mis, Dev	L, H	Cav, Por			100± 175± 50±	MC	Dev	3,725
6	Salt sand.-Maxon, Black shale, Corniferous	Pen, Mis, Dev	S, H, SL	Por	1,650±	2,200±	50, 400, 150	T	Ord	4,669
7	Big "6"	Sil	S	Por	1,750–1,900	1,728–1,875	25±	A	Sil	
8	Tarr Springs (Jett sand)	Mis	S	*x*	133	147	12	A	*x*	*x*
9	Salt sand (Jett) Tarr Springs	Mis	S	*x*	150	170	20	T		*x*
10	Tarr Springs (Jett sand)	Mis	S	*x*	377	392	15	T		*x*
11	Tarr Springs (Jett)	Mis	S	*x*	856	885	*x*	T		*x*
12	(Jones sand) Hardinsburg	Mis	S	*x*	516	506	10	A	*x*	*x*
13	Corniferous	Dev	LS	Por	1,550–1,700	1,525–1,675	20±	A, M	Dev	2,284
14	Corniferous	Dev	LS	Por			25	A, D	Dev	
15	Salt Sand	Pen	S	20	*x*	*x*		F, A	Mis	2,132
16	Blue Sand	Sil	L	Cav	700–850	780–1,300	15±	T, MC, A	Sil	*x*
17	McCloskey	Mis	OL	10–14	1,870	1,890	10	A	Mis	2,100
18	McCloskey	Mis	OL	10–14	2,101	2,117	10	A	Mis	2,200
19	Weir Dev. shale (gas)	Mis Dev	S, H, LS		825–1,350	875–1,500	40, 20, 350	A	Dev	1,780
20	Corniferous	Dev, Sil	LS, S	Por	85–960	120–1,000	40	AF	Ord	
21	Corniferous	Dev, Sil	LS, S	Por	550–900	520–870	20±	T	Ord	
22	Corniferous	Dev, Sil	LS, S	Por	75–375	100–400	25	AF	Ord	
23	Salt sand, Maxon, B Lime, Big Injun, Dev. Shale, Corniferous	Pen, Mis, Dev	S, L, LS, H	Por, Cav	900–3,100	1,100–3,500	15–550	A, D, MC, T, N, S	Sil	3,643
24	Maxon, Big Lime, Big Injun	Mis	S, LS	Por, Cav	950–1,475	1,000–1,500	15±	ML, MC, T	Ord	3,706
25	Trenton	Ord	LS	Por	225–335	240–350	15±	D	Ord	967
26	Triplett, Jones	Pen Mis	S	Por	580	600	30±	D, A	Mis	*x*
27	McCloskey	Mis	OL	*x*	2,176	2,180	*x*	D	Mis	3,000
28	Beaver Sunnybrook	Mis Ord	LS	Por	385–680	400–700	12	S	Ord	1,921
29	McCloskey	Mis	O, L	*x*	1,395	1,403	12	A	Dev	3,217
30	Tarr Springs (Jett)	Mis	S	20	650–700	725	40	A	Trenton	4,020
31	Pottsville	Pen	S	15	585	600	15	Channel	Mis	1,250
32	Jett and Barlow	Mis	S	12	725	750	5–30	T A	Mis	950
33	Weir Corniferous	Mis Dev	S, LS	Por	740–1,160	780–1,200	40±	D	Ord	3,719
34	Weir	Mis	S	Por	700–1,000	760–1,060	60±	D	Sil	
35	Weir	Mis	S	Por	900–960	860–1,220	35	D A	Ord	3,815
36	Weir, Berea	Mis	S	Por	600–1,060	640–1,100	3	DF, A, S	Dev	
37	Maxon, Big Lime, Shale	Mis, Dev	S, L, H	Por, Cav	1,425	1,800	40± 350±	[i]	Dev	1,816
38	Weir, Big 6	Mis, Sil	S, LS	Por	670–1,070 2,050–2,450	700–1,100 2,100–2,500	30±	A	Dev	
39	Salt sand, Maxon, Big Lime, Big Injun, Dev shale	Pen, Mis, Dev	S, L, H	Por, Cav	1,250–3,000	1,300–3,500	20 500	A, AM, H, MC, D, T, S	Ord	3,706
40	Big Lime	Mis	L	Cav	1,500	1,550	20	T	Mis	1,552
41	Salt sand	Pen	S	Por		200–500	15±	A		

[i] Depositional.

In eastern Kentucky the most important new development is the extensive leasing being done in that section by a number of the major oil companies. Leases amounting to several hundred thousand acres have been taken on all of the known and mapped structures, and on

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
42	Artemus-Himyar gas, *Knox*	1928		4,600EW 5,000		
43	Cain, *Lawrence*	1929		550	0	0
44	Louisa, *Lawrence*	1913	1,*xxx*		1,601,378	33,185
45	Big Sinking, *Lee, Estill, Powell, Wolfe*	1919	14,100		39,106,*xxx*	1,048,168
46	Goocey, *Lee*	1921			76,*xxx*	
47	Ida May, *Lee*	1926	377		758,*xxx*	54,730
48	Trabue, *Lee*	1930			132,*xxx*	12,350
49	Burning Fork, *Magoffin*	1923	918		1,812,940	52,965
50	Ivyton-Licking and Mine Fork gas, *Magoffin*	1920		6,840		
51	Martin Co. oil and gas, *Martin*	1897	210	90,900	262,680	81,265
52	Oklahoma, *Ohio*	1938	250		14,*xxx*	6,*xxx*
53	Habit, *Daviess*	1930	100		29,*xxx*	6,*xxx*
54	Owensboro, *Daviess-Ohio-McLean-Hancock-Breckenridge*	1922	10,800		30,*xxx*,*xxx*	3,*xxx*,*xxx*
55	Red Hill, *Daviess*	1927	400		596,*xxx*	51,*xxx*
56	Cumberland-Clinton, *Cumberland-Clinton*	(Abandoned. No Production.)				
57	Green Taylor gas, *Green, Taylor*	1921	(Abandoned)			
58	Menifee oil pool, *Menifee*	1922			231,835	
59	Rothwell gas, *Menifee*	1902		15,360		
60	Cannel City (Abandoned in 1937), *Morgan*	1914	600		378,507	
61	Muhlenberg, *Muhlenberg*	1929			299,958	30,734
62	Buffalo Cr. oil pool, *Owsley*	1923	12		33,*xxx*	1,*xxx*
63	Barrett Hill, *McLean*	1929	250		983,*xxx*	49,*xxx*
64	Bates Knob, *McLean*	1935	20[3] 350[4]		215,*xxx*	15,*xxx*
65	Birk City and Gilmore, *McLean-Daviess*	1938	850		1,3*xx*,*xxx*	740,382
66	Hackett, *McLean*	1936	150		630,*xxx*	80, *xxx*
67	Island Creek (Abandoned in 1934), *Owsley*	1928	20		9,899	
68	Needmore gas field, *Owsley*	1920		6,400		
69	Pebworth, *Owsley*	1924	60		71,*xxx*	0
70	Perry Co. (Hazard), *Perry*	1930		1,400		
71	Pike Co. gas field, *Pike*	1930		58,400		
72	Ashley, *Powell*	1918	1,091		3,198,*xxx*	111,056
73	Powell gas, *Powell*	1932				
74	North Triplett gas, *Rowan*	1905		1,200		
75	Island, *McLean*	1937	150		24*x*,*xxx*	1*x*,*xxx*
76	Livermore, *McLean*	1935	545		1,4*xx*,*xxx*	1*xx*,*xxx*
77	Williamsburg oil and gas pool (abandoned), *Whitley*	1904	700		4,000	
78	Campton-Stillwater, *Wolfe*	1913	1,447		673,945	11,832

[3] Oil and gas
[4] Gas.

structures where formerly gas fields existed which were exhausted and for which the leases have been surrendered. The purpose of this leasing is to seek production from deeper pay zones, especially those from the top of the Corniferous down to the St. Peter sandstone. Only a few wells have been drilled to a depth sufficient to reach the St. Peter sand

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
42	y	y	19								310	310			
43	0	0	9			9	9								
44			286			52	286			234				38	
45			2,5xx	xx	xx		2,5xx						SR	40	
46			13				11			11			SR		
47			12x	x			12x			11x					
48			15				15			15				41	
49			159				159			159				37	
50															
51	y	y	332	18	0		29	300		29				38	
52			19	0	0		19			19	x			36	
53			12				12			12				35	
54			3,xxx							2,xxx				35	
55			50				50			50	x	x		34	
56															
57			1xx					1xx							
58			150				0								
59	y	0													
60			75				0								
61			20				20			20					
62			7				4			4				41	
63			57	0	0		57				320	40		35.5	
64			27	0	1	0	26	0		26	405			36	
65			109	40	2	0	107			107				38	x
66			54				54			54	405	x		36.4	
67			6				0				317			39	
68			48					3x							
69			15	0	0	0	15								
70	y	y	9		2	2		2							
71	y	y	200	7	0			19x							
72			5xx	xx[2]			45x			4xx			SR		
73			2x	2				2x							
74			10		0			10			45				
75			14				14			14				36	
76	30x	x	170		10	1	158			148				34.5	
77			30	0	0		25	5			240				
78			275				7x		7x	7x					

and none of these on well defined structures, but the indications in them are such as to show production possible and probable.

With a firmer price for crude, this section undoubtedly will see much activity in deeper drilling.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Ne Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
42	Maxon, Brown shale, Corniferous	Mis, Dev	S, H LS	Por	1,080–2,000	1,100–2,100	30± 175± 100±	A, AF, D	Dev	2,225
43	Corniferous	Dev	LS	Por	1,650–1,740	1,670–1,760	18	MC	Dev	1,983
44	Berea	Mis	S	Por	1,575–1,875	1,600–1,900	2*x*		Ord	4,975
45	Corniferous	Dev, Sil	S, LS	Por	650–1,150	700–1,200	30	MC	Pre-Cam	2,*xxx*
46	Corniferous	Dev, Sil	LS, S	Por					Sil	
47	Corniferous	Sil, Dev	S, LS	Por	975–1,175	1,000–1,200	20	MC	Sil	
48	Corniferous	Dev, Sil	LS, S	Por	900–1,100	940–1,100	20±	MC	Ord	
49	Weir	Mis	S	Por	1,040–1,360	1,080–1,400	30	D	Ord	3,900
50	Weir, Black Shale, Corniferous, Salt sand, Maxon, Big Lime, Big Injun	Pen, Mis, Dev	S, H L	Por, Cav	1,050–1,350	1,100–1,400	40± 450±	D, A, MC, T, S	Ord	3,950
51	Oil-Maxon. Gas-S, S, Maxon, Big Lime, Dev shale	Dev, Mis, Pen	S, L, H	Por, Cav	700–3,000	1,100–3,300	10 600	A, AF, D, T MC, S	Dev	
52	Tarr Springs (Jett sand)	Mis	S		605	615	10	T	*x*	*x*
53	Fuqua Stray	Mis	S	18–20	910	930	20		Mis	1,350
54	Fuqua Stray, Pottsville, Pottsville, Jett, Jones, Barlowe, and Bethel	Pen, Mis	S	18–20		400–1,300	2–75	AN, A, T, D	Dev	*x*
55	Jett	Mis	S	18	970	1,015	14	A	Mis	1,020
56	Sunnybrook, Trenton	Ord	S, LS	Por				A, D	Cam-Ord	1,934
57		Ord	LS	Por	370–680	390–700	20±			
58	Corniferous	Dev	LS	Por	1,020–1,230	1,040–1,250	20	MC	Ord	
59	Corniferous, Ragland sand	Dev	LS	Por	500–650	550–700	40±	D	Ord	
60	Corniferous	Dev	L	Por	1,780–1,980	1,800–2,000	20	AF	Dev	
61	McCloskey	Mis	LS	Por	1,240–1,690	1,250–1,700	10±	D	Dev	*x*
62	Big Lime	Mis	LS	Por	1,110	1,125	15	A	Dev	1,962
63	Jett, Jackson, Barlow, Bethel	Mis	S	15–20	800–1,200	1,250	2–75	AF	Dev	3,250
64	Pottsville, Bethel, Barlow, and Bethel Lime	Pen, Mis	S, L	12–15	340–1,670	400–1,700	20	AF	Mis	1,906
65	McCloskey	Mis	L	10–14	2,050	2,100	7	A	Mis	2,200
66	Tarr Springs, Bethel	Mis	S	20	1,100–1,500	1,150–1,450	22	A	Mis	1,525
67	Big Lime	Mis	L	Cav			10–40		Dev	
68	Corniferous	Dev	LS	Por	850–1,150	900–1,200	40±	MC	Dev	
69	Corniferous	Dev	LS	Por			20±	MC	Dev	
70	Salt sand, Big Lime, Devonian shale	Pen, Mis, Dev	S, L H	Por Cav	2,200–2,900	2,700–3,300	50–500	MC	Dev	3,637
71	Salt sand, Maxon, Big Lime, Big Injun, Dev. shale	Pen, Mis, Dev	S, L, H	Por, Cav	800–4,000	850–4,500	10–800	A, AM, H, MC, D, T, S	Ord	5,343
72	Corniferous	Dev, Sil	LS, S	Por	550–950	600–1,000	40	AF	Ord	
73	Corniferous	Dev	LS	Por			20±	MC		
74	Corniferous	Dev	LS	Por	335	350	11	MC	Ord	1,501
75	Tarr Springs (Jett sand)	Mis	S		1,450	1,470	20	A	Dev	3,817
76	Barlow, Bethel	Mis	S	15–20	1,300–1,400	1,400	20	AF	Dev	3,242
77	Salt sand, Big Lime	Pen, Mis	S, L	Por, Cav	Gas 850± 1,700±	Oil 900± 1,750±	Oil 30± Gas 20±	A	Ord	3,350
78	Corniferous	Dev	LS	Por			25	AD	Dev	2,190

Oil and Gas Development in North Louisiana in 1939

By H. K. Shearer,* Member A.I.M.E.

(New York Meeting, February 1940)

Oil production in north Louisiana† in 1939 was 25,249,640 bbl., a decrease of 11.2 per cent from 1938. The only important increases in production were in the Cotton Valley and Shreveport fields, but Caddo, Homer, Sligo and Zwolle also made slight gains. Greatest decreases were in the Lisbon and Rodessa fields.

Natural gas production of 313,333 million cu. ft. was an increase of 5.6 per cent over 1938. The increase was accounted for in the Monroe field, while all other fields showed only minor variations from the production of the previous year.

Well completions in 1939, as compared with 1938, were as follows:

Year	Oil	Gas	Dry	Total	Wildcat Producers	Wildcat Dry Holes
1938	350	117	141	608	2	47
1939	278	83	160	521	1	48

The decline in number of completions was due entirely to lack of proved areas for drilling, and would have been greater except for a revival of interest in the old Caddo shallow field. A majority of the wells completed during the year were in various old, shallow fields, so the average depth of drilling was much less than in several preceding years, notwithstanding a few very deep tests.

No new fields were discovered, the only wildcat well reported as a producer being a very small oil well in northwestern De Soto Parish, which is of no apparent commercial importance. Deep gas-distillate production in the Cotton Valley formation was opened at Lake Bistineau and Lisbon, and oil at Shongaloo, but all these wells were too small to encourage additional drilling.

Extensions and Developments

Caddo Field.—More active drilling was done in the 36-year old Caddo field in 1939 than in any of the newer fields, with completion of 133 oil

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† Covers all townships north of Louisiana Base Line; i.e., 26 northern parishes and parts of Avoyelles, Rapides and Vernon, but not the Cheneyville and Eola oil fields in Rapides and Avoyelles.

wells, 3 gas wells and 66 dry holes. An extension southwest of Vivian, opened late in 1938, led to the drilling of 23 oil wells and 32 dry holes in T. 22 N., R. 16 W., with all producing wells completed in the lenticular Tokio-Paluxy sand at depths of 2450 to 2650 ft. In November the Temple Oil Corporation's No. 1 Bostwick, sec. 13, T. 22 N., R. 16 W., producing at the rate of 1500 bbl. per day at 2559 ft., indicated another extension northeast of Vivian, but several dry holes were also completed in that vicinity.

Of the Caddo wells, 67 produced from the Saratoga-Annona chalk at depths of 1350 to 1750 ft. In spite of close drilling in the past, occasional wells produce several hundred barrels per day from this formation after acid treatment.

The deepest and most disappointing test was the Stanolind Oil & Gas Company's No. 131 Dillon Heirs, sec. 14, T. 21 N., R. 15 W., in the center of the Pine Island "dome" in the Caddo field. Drilled to a total depth of 11,419 ft., it reached the top of the Cotton Valley formation at 5994 ft., had no definite "Buckner" formation, found top of the Smackover limestone equivalent at 8952 ft., drilled through 1247 ft. of rock salt from 10,158 to 11,405 ft., and was in hard igneous rock for 2 ft. at bottom. All formations below the upper Travis Peak were lacking in porosity and permeability. A number of tests of slightly porous zones in the Cotton Valley formation below 6943 ft. were made, but the well was finally completed in January 1940 as a very small gasser in the upper Travis Peak sand at 3903 to 3938 feet.

Cotton Valley Field.—Drilling at Cotton Valley declined in 1939. Most of the wells were drilled for oil in the "Holloway" sand or in deep sands on the flanks of the structure. Completions numbered 14 oil and 2 gas wells in the Holloway, 11 oil and 1 gas-distillate in the "D" sand, 6 oil and 10 gas-distillate in the "Bodcaw" sand proper. Three dry holes were abandoned just below the Holloway sand; and only one, on the extreme southwest flank, was drilled through the Bodcaw zone.

Recycling of gas from the Bodcaw sand was tried on an experimental scale for a period of 29 days during 1939, using two wells for production and one for injection. Results indicated that recycling and pressure maintenance are technically practicable, and data for formulating a field-wide project were obtained. Separators operated at 1600 to 2100 lb., obtaining 3 gal. per 1000 cu. ft. of 62° gravity condensate, and injection pressure of the dry gas averaged a little more than 3000 lb. per sq. inch.

Lisbon Field.—The Lisbon Exploration Company's No. 1 Vaughn, sec. 36, T. 21 N., R. 5 W., a depleted producer in the "Pettit" zone at 5313 ft., was deepened to 8900 ft., penetrating 1100 ft. into the Cotton Valley formation. It was completed through perforations at 8444 to 8464 ft. in December 1939 as the deep-sand discovery, but was not a large producer, making 65 bbl. per day of 53° gravity distillate with about 3,000,000 cu. ft. of gas. This gas will probably be used for repressuring the Pettit limestone zone. Only four small oil wells were completed in the Pettit, and oil production declined almost 50 per cent.

Rodessa Field.—Rodessa oil production declined 4,427,700 bbl. in 1939, but it still produced 36 per cent of the north Louisiana total. Only 14 oil wells and 1 gas well were completed during the year, all being in the northeastern extension, near the Arkansas line.

Shongaloo Field.—The second Cotton Valley formation gas-distillate well on the Shongaloo structure was completed in February at a depth of 9202 ft. In June the Magnolia Petroleum Company's No. 1 Roseberry Unit, sec. 29, T. 23 N., R. 9 W. was completed as the discovery oil well in the same formation, flowing by heads 130 bbl. per day of 48° gravity oil at 9182 ft., plugged back from 9380 ft. These deep wells were not large enough to encourage any more drilling.

Shreveport Field.—The Shreveport field, which had only eight producing wells at the beginning of the year, was almost completely developed by the completion of 43 more oil wells, mostly on 40-acre spacing. The producing area is defined by dry holes and unprofitable wells, showing it to be an oil field of minor importance.

Deep Gas Fields.—The Lake Bistineau field in Bienville Parish was most active of the deep gas-distillate fields. Six wells were completed in the regular producing member of the Pine Island formation, and a deeper zone was discovered. The Arkansas-Louisiana Gas Company's No. 2 Gayoso Company, sec. 14, T. 16 N., R. 10 W. was completed in July, producing from several sands between 8110 and the total depth of 8532 ft. The top of the producing zone is about 300 ft. below the top of the Cotton Valley formation. However, the porosity was not very good, as initial production reported was only 2,500,000 cu. ft. per day of gas, with a spray of distillate and a slight show of salt water.

In Waskom field, Caddo Parish, the Arkansas-Louisiana Gas Company's No. 1 W. M. Bell, sec. 6, T. 17 N., R. 16 W., was completed in November, producing 10,500,000 cu. ft. per day of gas from sands in the upper part of the Travis Peak formation between 5915 and 6100 ft., total depth 6400 ft. This is the first test drilled below the Glen Rose anhydrite in the Louisiana part of the field, but there were already four deep gas wells on the Texas side of the same structure. This well extended the deep production 2½ miles northeast.

In Sibley field, Webster Parish, there were no new producers, but one of the deepest tests of the year was drilled. In an attempt to extend the field 2 miles northeast, the Union Producing Company's No. 1 Walker Unit, sec. 30, T. 18 N., R. 8 W. was dry at 10,383 ft., several hundred feet in the Cotton Valley formation. Practically no porosity was found in the Travis Peak and Cotton Valley formations, and the well

TABLE 1.—*Oil and Gas Production in North Louisiana*

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Bear Creek, *Bienville*	1937	0	2,500	0	0
2	Bellevue, *Bossier*	1921	1,360	160	10,309,885	209,490
3	Bethany-Waskom, *Caddo*[1]	1916	20	15,000	0	0
4	Caddo, *Caddo*[2]	1904	32,500	5,000	156,520,420	2,563,230
5	Carterville, *Bossier*	1927	720	2,720	1,574,510	39,700
6	Clayton, *Concordia*	1931	0	60	0	0
7	Converse, *Sabine*	1932	2,000	0	2,114,510	187,050
8	Cotton Valley, *Webster*		13,000		23,630,650	4,270,585
9	Shallow, gas and heavy oil	1922	2,600	6,600	14,941,440	14,320
10	Holloway, light oil	1936	1,880		3,340,271	1,444,596
11	Bodcaw, gas-distillate	1937		11,000	3,616,263	1,328,965
12	Bodcaw, light oil	1938	2,000		1,732,676	1,482,704
13	De Soto-Red River, *De Soto, Red River*	1912	11,000	3,300	57,726,385	411,495
14	Driscoll, *Bienville*	1936	0	1,000	0	0
15	Elm Grove, *Bossier, Caddo*	1916	320	14,600	3,552,910	100,045
16	Epps, *East Carroll, West Carroll*	1928	0	1,200	0	0
17	Haynesville, *Claiborne*	1921	7,480	0	69,929,850	1,041,385
18	Holly, *De Soto*	1930	80	160	962,920	29,350
19	Homer, *Claiborne*	1919	3,020	0	69,263,110	992,935
20	Lake Bistineau, *Bienville*	1916	0	2,240	0	0
	Lisbon, *Claiborne, Lincoln:*					
21	Oil	1936	7,500	0	7,420,965	1,698,315
22	Gas-distillate	1939	0	160	0	0
23	Logansport, *De Soto*	1938	0	2,000	0	0
24	Monroe, *Morehouse, Ouachita, Union*	1916	0	270,000	0	0
25	Pleasant Hill, *Sabine*	1927	800	0	1,556,570	35,530
26	Richland, *Richland*	1926	0	49,280	0	0
27	Rodessa, *Caddo*	1930	9,400	7,800[3]	61,058,920	9,204,020
28	Ruston, *Lincoln*	1937	0	160	0	0
29	Sarepta, *Bossier, Webster*	1922	570	1,120	1,584,589	58,204
	Shongaloo, *Webster:*					
30	Shallow	1921	70	5,680	116,115	7,535
31	Deep	1938	80	1,000	87,646	47,821
32	Shreveport, *Caddo*	1938	2,500	240	1,978,875	1,865,305
33	Sibley, *Webster*	1936	0	640	0	0
34	Simsboro, *Lincoln*	1935	0	320	0	0
35	Sligo, *Bossier*	1922	800	12,000	937,895	436,465
36	Sugar Creek, *Claiborne*	1931	60	4,000	360,155	125,685
37	Sutherlin-Spider, *De Soto*	1935	0	320	0	0
38	Urania, *Grant, LaSalle, Winn*	1925	3,700	0	24,261,585	969,770
39	White Sulphur Springs, *La Salle*	1928	80	0	12,290	0
40	Zwolle, *Sabine*	1928	7,520[4]	0	14,921,245	955,725
41	Total		98,060	413,660	509,882,000	25,249,640

[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Includes the part of Bethany and Waskom fields in Louisiana; also Blanchard, Longwood, Greenwood, Cedar Grove, Spring Ridge and old Cross Lake areas.

[2] Includes Mooringsport, Trees City, Vivian, Hosston, Pine Island, Gilliam and Dixie areas.

[3] Most Rodessa acreage produces both oil and gas; classification of oil or gas wells depends on gas-oil ratios.

[4] Allowing 20 acres per producing well, but the Zwolle field is scattered over a much larger area.

Table 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939[5]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity, A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
1	686	658	5	2	0	0	0	5			2,660	2,660			
2	2,463	92	422	9	0	*y*	150	1	0	150	*y*	*y*	SR	19	0.80
3	18,753	521	181	1	6	16	0	25			1,880 2,380	*y* 2,380			
4	139,078	1,484	4,388	136	134	36	1,218	46		1,218	*y*	*y*	SR	25 40	0.50
5	17,051	20	155	0	21	*y*	13	3	0	13	1,250	*y*		42	0.77
6	11	0	1	0	0	1	0	0	0	0	630	620			
7	2	2	181	6	19	18	59	0	0	59	*y*	*y*		42	0.15
8	128,804	23,379	429	44	69	*y*	71	83	62	9					
9	*x*	*x*	279	0	69	*y*	4	0	0	4	*y*	*y*		25	0.25
10	*x*	*x*	47	16	0	0	44	3	39	5	2,525	800		50	*y*
11	*x*	*x*	80	11	0	0	0	80			3,930	3,600		64	*y*
12	*x*	*x*	23	17	0	0	23	0	23		3,930	3,600		51	*y*
13	65,127	1,154	1,432	4	33	*y*	140	24		140	*y*	*y*	SR	40	0.25
14	6,071	2,588	4	0	0	0	0	4			2,375 2,830	1,730 2,000			
15	193,078	1,183	248	0	7	*y*	34	50		34	*y*	*y*		29	0.40
16	6,385	1,249	4	0	0	0	0	4			1,060	830			
17	3,534	820	766	0	4	*y*	287	0	0	287	*y*	*y*	RP	36	0.40
18	136	13	15	0	1	0	4	2	0	4	*y*	*y*		37	0.22
19	6,343	390	633	4	4	*y*	355	0		355	*y*	*y*	SR	36	0.63
20	2,541	416	20	7	0	2	0	8			2,310	2,150			
21	2,976	907	266	4	26	*y*	228	0	65	163	2,000	400		34	1.30
22	*x*	*x*	1	1	0	1	0	0			2,900	2,900			
23	0	0	1	0	0	1	0	0			2,423	2,423			
24	2,621,542	189,557	1,313	49	45	115	0	1,081			1,020	50–950			
25	259	104	62	0	1	10	18	1	0	18	*y*	*y*		40	0.30
26	450,615	2,842	313	0	119	0	0	5			1,125	40–200			
27	280,026	60,251[6]	499	15	6	32	360	101[3]	176	184	2,780	1,107[7] 217		44 65	0.10
28	0	0	1	0	0	1	0	0			2,134	2,134			
29	25,593	12	44	0	0	*y*	6	0		6	1,200	0		25	0.32
30	72,134	431	91	0	2	*y*	2	1		2	1,200	*y*		29	0.35
31	*x*	*x*	3	2	0	0	1	2	1	0	*x*	*x*		64	*y*
32	3,052	2,952	51	43	0	4	47	0	47	0	2,602	1,145		44	*y*
33	339	282	4	0	0	1	0	3			2,400	2,350			
34	5,218	1,562	2	0	0	0	0	2			2,100 2,620	550 2,500			
35	87,522	14,328	122	6	0	*y*	26	61	6	20	1,890 2,200	1,675 2,000		42	*y*
36	43,967	6,135	17	1	0	0	2	15	2	0	1,800 2,310	340 1,800		39	*y*
37	221	0	5	0	0	2	0	0			1,200	800			
38	6	0	513	10	13	*y*	253	0	0	253	*y*	0		18	0.30
39	0	0	12	0	0	0	0	0	0	0	*y*	0		20	*y*
40	180	1	376	16	15	16	47	0	0	47	*y*	0		40	0.10
41	4,183,713	313,333	12,580	360	525	256	3,321	1,527	359	2,971					

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[5] Gas production figures were supplied by Clarence P. Dunbar of the Louisiana Department of Conservation. Casinghead gas production is included, totaling 39,401 million cu. ft. in 1939, of which 30,875 million cu. ft. was from the Rodessa field.

[6] The Rodessa Operators Committee estimates Rodessa gas production for 1939 as 59,772 million cu. ft. (41,316 million to pipe lines and 18,456 million to air); cumulative total to Dec. 31, 1939 as 466,158 million cu. ft. (234,673 million to pipe lines and 231,485 million to air).

[7] Weighted average, Dees-Young, 1107; Gloyd, 217 lb.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	Pine Island, Travis Peak	CreL	OL, S	Por	6,665 7,320	6,695 7,879	*y*	A	Travis Peak	8,017
2	Nacatoch Rodessa	CreU CreL	S	Por	360 1,010	370 1,035	25	AF	Cotton Valley	6,137
3	[8]	CreU CreL	S, OL	Por	[8]	1,000- 6,100	*y*	A	Cotton Valley	9,244
4	[9]	CreU CreL	S, C, OL, L	Por	[9]	1,000- 4,000	*y*	Af	Igneous below salt	11,419
5	Buckrange, Tokio	CreU	S	Por	3,050 3,140	3,060 3,150	9	A	Cotton Valley	10,066
6	Jackson	Eoc	S	Por	1,415	1,438	25	N	Wilcox	3,705
7	Saratoga-Annona Paluxy, Rodessa	CreU, CreL	C, L	Fis Por	1,617 3,150	1,922 3,232	*x*	Af	Travis Peak	8,929
8								A	Cotton Valley	9,198
9	Buckrange Rodessa	CreU, CreL	S S, A, OL	Por	2,532 4,350	2,547 4,652	11 *x*	A		
10	Travis Peak	CreL	S	10	5,692	5,987	15	AL		
11	Cotton Valley	Jur?	S	17	8,270	8,650	40	A		
12	Cotton Valley	Jur?	S	17	8,570	8,650	40	A		
13	[10]	CreU CreL	S, C	Por	[10]	825–3,500	*y*	AF	Pine Island	6,488
14	Rodessa Travis Peak	CreL	OL, S	15	5,862 7,160	5,880 7,216	18 50	A	Travis Peak	7,693
15	Nacatoch Ozan, Tokio	CreU	S	Por	804 2,469	840 2,496	*y*	A	Pine Island	5,382
16	Monroe gas rock	CreU	LS	Por	2,336	2,344	8	D	Igneous	3,142
17	Buckrange	CreU	S	Por	2,655	2,680	25	A	Pine Island	5,092
18	Eagle Ford?	CreU	S	Por	2,538	2,581	11	NL	Paluxy	3,373
19	Nacatoch Buckrange	CreU	S	Por	1,280 2,040	1,345 2,065	63	AF	Cotton Valley	4,504
20	Ozan, Tokio, Pine Island, Cotton Valley	CreU, CreL, Jur?	S, OL	Por	5,100 8,400	5,200 8,532	50	Af	Cotton Valley	8,532
21	Pine Island	CreL	O	20	5,275	5,300	12	N		
22	Cotton Valley	Jur?	S	Por	8,444	8,464	20	A	Cotton Valley	8,900
23	Rodessa	CreL	OL	Por	4,953	5,187	30	A	Rodessa	5,187
24	Monroe gas rock	CreU	LS	23	2,145	2,205	50	A	Jurassic?	10,475
25	Paluxy	CreL	L, S	Por	3,175	3,237	16	Nf	Glen Rose	5,063
26	Monroe gas rock Tokio, Glen Rose	CreU CreL	S, LS	Por	2,349	2,447	76	A	Cotton Valley	9,986
27	Rodessa	CreL	S, L LS, OL	5–35	5,560 6,675	5,600 6,100	5–80	AF	Pre-Cre, salt	11,486
28	Pine Island	CreL	OL	Por	5,316	5,822	10	A	Travis Peak	5,822
29	Buckrange	CreU	S	Por	2,681	2,700	11	A	Rodessa	5,120
30	Buckrange	CreU	S	20	2,665	2,680	12	A		
31	Cotton Valley	Jur?	S	Por	9,000	9,680	20	A	Smackover?	10,462
32	Pine Island	CreL	OL	Por	5,550	5,581	15	A	Travis Peak	6,025
33	Rodessa	CreL	OL	Por	5,570	6,112	40	A	Cotton Valley	10,383
34	Rodessa Travis Peak	CreL	OL, S	Por	5,282 6,451	6,301 6,576	30	A	Travis Peak	7,023
35	[11]	CreU, CreL	S, OL	Por	[11]	850–5,200	30	A	Travis Peak	6,112
36	Rodessa Pine Island, Travis Peak	CreL	OL, S, SL	18 Por	4,370 5,700	4,400 5,730	13 50	A	Smackover?	10,759
37	Paluxy	CreL	S	Por	2,840	2,850	10	AL	Pine Island	5,930
38	Cane River-Wilcox	Eoc	S	Por	1,520	1,530	9	MU	Tokio	6,463
39	Jackson	Eoc	S	Por	794	804	9	NF	Wilcox	2,435
40	Saratoga-Annona Paluxy	CreU CreL	C L	Fis	2,100	2,500	*x*	Af	L, Glen Rose	7,155
41										

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[8] Different areas produce gas from Nacatoch at about 1000 ft.; Buckrange, 1950; Tokio-Paluxy, 2300; Rodessa, 4650; Pine Island, 5850; Travis Peak, 5900 to 6100.

[9] Production from Nacatoch at about 1000 ft.; Saratoga-Annona chalk, 1400 to 1900; "Blossom," 1825; Tokio-Paluxy 2250 to 2400; and at Pine Island, from Rodessa formation, 2800 to 3000; Pine Island formation, 3700 to 3800; Travis Peak 3900 to 4000.

[10] Production from Nacatoch at about 800 ft.; Saratoga-Annona chalk, 1400; Eagle Ford-Paluxy, 2600; gas from Paluxy, 3500.

[11] Production from Nacatoch at about 850 ft.; Buckrange, 1725; Tokio, 2450; Paluxy, 2750 and 3100; Rodessa, 4100 to 4275; Pine Island (Pettit member) 5100 to 5200.

tested dry in the regular Rodessa producing members at 5610 to 5860 feet.

In Sligo field, Bossier Parish, three "Pine Island" (Pettit zone) gas wells were completed, besides three oil wells in the 3100-ft. zone. In Bear Creek field, Bienville Parish, two gas wells were completed, one each in the Pine Island and Travis Peak formations, extending the field 2 miles northeast. One gas well was completed in the Pine Island-Travis Peak contact zone in Sugar Creek field, Claiborne Parish.

Monroe Field.—In the Monroe gas field 49 gas wells were completed in 1939; 9 in Morehouse Parish, 6 in Ouachita and 34 in Union. Gas withdrawals increased about 16 billion cu. ft., or almost 10 per cent.

One of the most important deep tests ever drilled in north Louisiana was drilled in the northern part of the Monroe gas field. The Union Producing Company's No. A-1 Tensas Delta Lumber Co., sec. 8, T. 22 N., R. 4 E. was drilled to 10,475 ft. The Cotton Valley formation was found at 4422 ft., followed by 886 ft. of Smackover limestone and equivalent beds from 7228 to 8114 ft., the typical Buckner formation being absent. There was 968 ft. of rock salt to 9082 ft. Below the salt was 231 ft. of red shale and anhydrite, then 1150 ft. of dark-colored shale, with 12 ft. of very hard sandstone in the bottom of the hole. Fossils found in the thick dark shale below the salt are reported to be definitely of Mesozoic

TABLE 2.—*Summary of Drilling Operations in North Louisiana in* 1939

Important Wildcats Drilled in 1939

	Parish	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by
		Sec.	Twp.	Rge.				
1	Avoyelles	8	2 N	4 E	6,600	Pleistocene	Wilcox	Adams Oil & Gas Co.
2	Bienville	14	16 N	10 W	8,532	Wilcox	Cotton Valley	Arkansas-Louisiana Gas Co.
3	Bienville	36	17 N	6 W	7,947	Claiborne	Travis Peak	Hunt Oil Co.
4	Bossier	19	19 N	13 W	6,041	Wilcox	Travis Peak	H. Hanbury et al.
5	Bossier	17	16 N	10 W	5,667	Wilcox	Travis Peak	Union Producing Co.
6	Caddo	6	17 N	16 W	6,400	Wilcox	Travis Peak	Arkansas-Louisiana Gas Co.
7	Caddo	29	17 N	13 W	6,003	Wilcox	Travis Peak	D. J. Crawford et al.
8	Caddo	19	18 N	14 W	5,608	Wilcox	Pine Island	J. P. Driscoll et al.
9	Caddo	3	15 N	12 W	6,010	Wilcox	Travis Peak	Prairie River Syndicate
10	Caddo	30	19 N	15 W	6,042	Wilcox	Travis Peak	J. O. Whittington et al.
11	Caddo	14	21 N	15 W	11,419	Wilcox	Igneous rock below rock salt	Stanolind Oil & Gas Co.
12	Caldwell	31	12 N	3 E	7,538	Claiborne	Upper Glen Rose	Arkansas Fuel Oil Co.
13	Catahoula	33	11 N	8 E	5,023	Pleistocene	Midway	Bell Drilling Co.
14	Claiborne	36	21 N	5 W	8,901	Claiborne	Cotton Valley	Lisbon Exploration Co.
15	Franklin	22	13 N	8 E	1,839	Pleistocene	Rock salt	Continental Oil Co.
16	Grant	5	5 N	3 W	5,057	Catahoula	Wilcox	Longwood Oil & Gas Co.
17	Morehouse	8	22 N	4 E	10,475	Claiborne	Jurassic?	Union Producing Co.
18	Rapides	35	1 N	3 W	7,523	Citronelle	Wilcox	Gulf States Exp. Co.
19	Tensas	31	13 N	12 E	4,172	Pleistocene	Rock salt	Continental Oil Co.
20	Union	14	23 N	2 W	8,755	Claiborne	Smackover	Standard Oil Co. of La.
21	Vernon	32	1 N	6 W	9,065	Citronelle	Wilcox	W. T. Burton
22	Webster	29	23 N	9 W	9,380	Claiborne	Cotton Valley	Magnolia Petroleum Co.
23	Webster	4	20 N	10 W	9,198	Claiborne	Cotton Valley	Oliphant Oil Corp.
24	Webster	30	18 N	8 W	10,383	Claiborne	Cotton Valley	Union Producing Co.

types, probably Jurassic. This well reveals an important series of beds whose existence was previously entirely unknown in the geology of North America.

The Smackover limestone in this well had some porosity, but showed salt water on testing. It was completed in February 1940 as a small gas well in the Monroe gas zone, after plugging back and perforating at 2163 to 2225 ft.

Richland Field.—Late in 1939 the United Gas Pipe Line Co. ceased purchasing gas in the Richland field. Some gas is still produced by five wells for local use, but future production will be negligible. The field had a total marketed production of some 450 billion cu. ft., or a little over 9,000,000 cu. ft. per acre from 49,280 acres. Probably a much larger quantity of gas was wasted from several wells that were allowed to crater during the early development.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.	Remarks
	Oil, U. S. Bbl.	Gas, Millions Cu. Ft.			
1					Dry
2	Distillate	3	Open	3,140	Discovery of gas-distillate in Cotton Valley formation, Lake Bistineau field
3	Distillate	1¼	7/64	2,900	Extends Bear Creek field 2 miles northeast
4					Dry. East of Dixie, north of Shreveport field
5					Dry. Limits Lake Bistineau field on west
6	Distillate	10½	Open	2,380	Extends Waskom field deep production 2 miles east and into La. Perforated 5915–6100
7					Dry. In old Cedar Grove gas field
8					Dry. Limits Shreveport field on northwest
9					Dry. In Caspiana area of Elm Grove field
10					Dry. Blanchard area
11	0	1½	2″ tbg.	889	Dry in deep zones, completed in Travis Peak at 3903–3938. Pine Island area, Caddo field
12					Dry. Northeast of Urania field
13					Dry. Deepest test in Parish
14	64 dist.	3	⅜	2,900	Perforated 8444–8464. Discovery of gas-distillate in Cotton Valley formation, Lisbon field
15					Dry. Discovery of a new salt dome
16					Dry. Deepest test in Parish
17	0	2½	Open	1,000	Dry in deep zones, completed in Monroe gas rock at 2163–2225. On north edge of Monroe field
18					Dry
19					Dry. Discovery of a new salt dome
20					Dry. Southeast of El Dorado, Ark., field
21					Dry
22	130	*y*	By heads	*y*	Plugged back to 9182. Discovery oil well in Cotton Valley formation, Shongaloo field
23					Dry. Deepest test and limits Cotton Valley field on southwest
24					Dry. Deepest test and limits Sibley field on northeast

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	57	11
Number of oil wells completed during 1939	277	1
Number of gas wells completed during 1939	83	0
Number of dry holes completed during 1939	112	48

Other Old Fields.—Among the other old fields, Zwolle was most active, with 16 oil wells and 21 dry holes completed, and a 21 per cent increase in production. Also, 6 oil wells were completed in Converse field, 10 in Urania, 9 in Bellevue, 4 in Homer and 4 in De Soto-Red River.

Salt Domes.—In Tensas Parish, the Continental Oil Company's No. 1 Cammack, sec. 31, T. 13 N., R. 12 E. was completed in July, discovering a new dome. Top of the salt was at 4123 ft. and total depth 4172 ft. In Franklin Parish, the Continental Oil Company's No. 1 Sherrouse, sec. 22, T. 13 N., R. 8 E. was completed in September, with top of the salt at 1778 ft. and total depth 1839 ft., as the discovery of the third and shallowest salt dome in the alluvial valley of the Mississippi. There have been no important showings of oil in any of the six tests drilled by the same company on these two domes and on one discovered in 1938 in Madison Parish.

Other Deep Tests.—Deep wildcat tests outside the fields include the following:

In Caldwell Parish, sec. 31, T. 12 N., R. 3 E., the Arkansas Fuel Oil Company's No. 1 La. Central Lumber Co. was drilled to 7538 ft., being the first deep test in that parish. It found an apparently normal section, with about 4500 ft. of Eocene beds, 2200 ft. of Upper Cretaceous, and penetrated more than 800 ft. of Lower Cretaceous, evidently Paluxy or upper Glen Rose, as no anhydrite was reached.

In northwestern Union Parish, sec. 14, T. 23 N., R. 2 W., the Standard Oil Company of Louisiana's No. B-1 Frost Lumber Industries was drilled to 8755 ft. It penetrated about 2840 ft. of Cotton Valley formation, which lacked good porosity; found no Buckner anhydrite, and reached the top of the Smackover limestone at 8627 ft. Some of the limestone was porous, but it carried salt water.

In Caddo and Bossier Parishes several unsuccessful tests were drilled to the Pine Island and Travis Peak around the Shreveport oil field. These are listed in Table 2.

In Catahoula, LaSalle and Grant Parishes, and in the northern townships of Avoyelles, Rapides and Vernon, 23 wells were drilled, mostly on geophysical prospects, to test the sands of the Sparta and Wilcox formations, which produce oil in Urania, Cheneyville and Eola fields. Depths ranged from about 2000 to more than 9000 ft. All were failures. The deeper and more important tests are listed in Table 2.

Conclusion.—Deep drilling in north Louisiana in 1939 did not encourage hopes for any large reserve of oil in deeper formations. Tests into or through the Cotton Valley formation have become fairly abundant. Three wells, not on salt domes, have reached the Jurassic (?) salt bed, and two have penetrated its entire thickness. In the pre-Cretaceous formations, small production has been found in the Cotton Valley formation at Lake Bistineau, Lisbon and Shongaloo, but satisfactory sand conditions are known to exist only at Cotton Valley. The Smackover limestone does not produce anywhere in Louisiana, and has had no satisfactory porosity in any wells south and west of Union and Morehouse Parishes.

Drilling activity and oil production may be expected to decline further in 1940. A few more deep tests are planned on known structures, including Haynesville and the area north of the Lisbon field, but the fact is that a substantial increase in prices of both oil and gas is needed to insure satisfactory profits from such productive formations as are known or indicated below a depth of 8000 ft. The Sparta-Wilcox trend across central and northeastern Louisiana still has possibilities for production at more reasonable depths.

Petroleum Developments in Southern Louisiana in 1939

By J. Brian Eby,* Member A.I.M.E.

(New York Meeting, February 1940)

The Gulf Coast area of Louisiana enjoyed a particularly active and profitable year in 1939. Fifteen new producing structures were located and approximately sixty new producing sand horizons in old fields were opened in that period of time.

The most important new discoveries are the Eola field, Avoyelles Parish, and the Paradis, St. Charles Parish. The Eola strike was indicated during December 1938, but the well was not placed on production until January 1939. Eola is particularly important because it was the first discovery of oil in a commercial quantity in the Wilcox formation in that area. Sid Richardson, of Ft. Worth, Texas, drilled the first well on the Haas Investment Company's property, which encountered the producing sand at a little below 8500 ft. Within the year 48 wells were drilled, 42 being commercial producers and 6 dry holes.

The second most favorable discovery was the Paradis field, which was discovered by The Texas Company's Louisiana Land and Exploration Company's Paradis No. 1 well, in St. Charles Parish, just west of New Orleans. Detailed information concerning this field has not yet been made available but it is reported that the oil sand is as much as 175 ft. thick. The initial production indicated was 1750 bbl. daily and reports suggest a very large structure.

In Calcasieu Parish the Humble Oil and Refining Company's Edgewood Land No. 1 discovered gas in the Oligocene at a total depth of 7042 ft., in the Perkins area. Although two additional dry holes have been drilled in this prospect, it is still believed to have some merit.

A new discovery is credited to Cameron Parish with the finding of Miocene oil in the Superior Oil Company's State No. 1 well in Grand Lake. The Chalkley field, Cameron Parish, is credited as a 1938 discovery but was largely developed in 1939 into one of the more important new fields. During the year 13 wells were drilled, 8 being oil wells and 5 dry holes. The oil is found in the Oligocene at depths of approximately 9000 feet.

Summarized at meeting; manuscript received at the office of the Institute April 24, 1940.

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TABLE 1.—*Oil and Gas Production in Southern Louisiana*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Abbeville, *Vermilion*	1937	160	0	374,308	164,648
2	Anse La Butte, *St. Martin*	1902	50	0	968,598	24,254
3	Bancroft, *Beauregard*	1938	640	*y*	911,209	895,555
4	Barataria, *Jefferson*	1939	40	*y*	17,046	17,046
5	Bateman Lake, *St. Mary*	1937	500	0	388,066	246,000
6	Bayou Blue, *Iberville*	1929	40		91,966	6,966
7	Bayou Bouillon, *St. Martin*	1902	52	10	422,622	13,801
8	Bayou Des Allemands, *St. Charles*	1937	100	20	157,998	62,582
9	Bayou Mallet, *Acadia*	1936	60	10	254,693	84,637
10	Bay St. Elaine, *Terrebonne*	1934	120	*x*	268,250	132,000
11	Big Lake, *Cameron*	1935	160	160	68,689	6,616
12	Black Bayou, *Cameron*	1929	100		7,000,000	1,050,000
13	Bosco (and Cankton), *Acadia, St. Landry*	1934	1,250		18,094,176	1,689,280
14	Caillou Island, *Terrebonne*	1930	400	0	27,438,288	4,081,000
15	Cameron Meadows, *Cameron*	1931	200+		6,555,940	795,104
16	Chacahoula, *Lafourche*	1938	400		380,761	331,000
17	Chalkley, *Cameron*	1938	1,500	500	217,000	216,000
18	Charenton (Inc. West Charenton), *St. Mary*	1936	375	0	3,634,491	2,344,127
19	Cheneyville, *Rapides*	1935	650*x*		784,309	361,813
20	Choctaw, *Iberville*	1931	120		2,646,047	408,174
21	Convent, *St. James*	1938			40,184	18,000
22	Creole, *Cameron*	1938	100	0	731,702	574,772
23	Crowley, North, *Acadia*	1937	500	0	1,203,000	815,300
24	Crowley, South, *Acadia*	Abandoned				
25	Darrow, *Ascension*	1932	200	0	3,566,000	1,042,000
26	DeLarge, *Terrebonne*	1938	*x*	*x*	48,205	34,346
27	Dog Lake, *Terrebonne*	1935	50	0	1,847,432	225,000
28	Edgerly, *Calcasieu*	1912	*y*	*y*	9,433,290	59,415
29	Elton, South, *Jefferson Davis*	1937	100	100	(dist.) 13,586	830
30	Elton, North, *Allen*	1939	0	320	0	0
31	Eola, *Avoyelles*	1939	2,000	0	1,015,616	1,015,616
32	Fausse Point, *Iberia*	1926	20	0	48,133	11,000
33	Four Isle, *Terrebonne*	Abandoned				
34	Garden Island Bay, *Plaquemines*	1935	250	0	2,403,037	592,000
35	Gibson, *Terrebonne*	1937	350	0	2,527,364	1,118,000
36	Gillis, *Calcasieu*	1934	1,050	150	18,082,617	1,927,735
37	Golden Meadows, *Lafourche*	1938	400	0	749,294	747,000
38	Grand Bay, *Plaquemines*	1938	320	0	547,972	495,195
39	Grand Lake, *Cameron*	1939	120	0	126,975	126,975
40	Gueydan, *Vermilion*	1932	25	0	1,032,624	150,511
41	Gueydan, West, *Vermilion*	1938	120	20	152,203	122,345
42	Hackberry (old), *Cameron*	1927	350	0	6,392,000	1,274,000
43	Happytown, *St. Martin*	1939	*x*	*x*	13,828	13,828
44	Hackberry, East, *Cameron*	1927	*y*	*y*	22,869,092	1,949,788
45	Henderson, *St. Martin*	1939	50	0	21,000	21,000

[b] Footnotes to column heads and explanation of symbols are given on page 239.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[e]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
1	1,484	883	8	3	1	0	8	0	8	0				42	−0.1
2	0	0	9	0	0	0	9	1	0	9	*x*	*y*		22	*y*
3	*y*	*y*	32	24	0	0	32	0	32	0	2,600			39.6	
4	15	15	1	1	0	0	1	0	1		3,300		0	36	
5			5	4	0	1	4	0	4	0	*x*	*x*		33	
6	*y*	*y*	8	1	0	*y*	2	0	0	2	650	375		19	*y*
7	*y*	*y*	56	1	0	1	1	1	0	2	*x*	*x*	0	25	*y*
8			3	1	0	0	2	1	3	0				36	0.11
9			5	0	0	0	5		5	0				30	
10			10	4	*x*	*x*	4	2	3	1				29	
11	275*e*[1]	43*e*	5	0	5	5	0	0	0	0	1,825	0	0	38.8	
12	3,500*e*	500*e*	27	0	0	3	19	0	10	9		2,180	0	25	0.15
13			69	0	3	1	56		56	0			PM	38.8	
14			45	6	0	4	41	0	31	10	*y*	*x*		34	
15			56	1	3	1	32	0	0	32					0.3
16			4	2	2	0	4	0	4	0			0	32.5	0.14
17	*x*	*x*	10	9	0	0	8	2	8	0	*y*	*y*	0	36	0.12
18			144	101	1	3	139		18	119		*y*		19–37	0.2
19	6,637	1,357	22	14	2	0	19	1	19		2,300	1,600*y*	0	36.6	0
20			12	2	1	0	12	0	8	4				27–39	0.11
21			2	1	0	1	1	0	1	0				38	0.10
22			9	6	0	0	9	0	9	0				34	
23			17	6	0	0	17	0	17	0	*y*	*y*	0	35	0.17
24															
25			24	5	0	1	14	0	14	0	*y*	*y*	0	38.5	0.12
26	*y*	*y*	2	0	1	0	1		1	0	6,250	6,250	0	50.8	0.10
27			12	3	0	4	8	0	8	0				39	
28	*y*	*y*	*y*	1	13	*y*	15	*y*	*y*	*y*	*y*	*y*		27	
29			2	0	0	0	1	1	1	0			0	52	0.10
30	0	0	2	2	0	2	0	0						57.1	
31	1,219	1,219	47	47	0	0	47	0	47	0	3,700	3,650	0	43	
32			2	1	0	0	2	0	2	0				37	
33															
34			23	7	0	6	15	1	15	0				37	
35			14	1	0	1	13	0	13	0				37	
36	*x*	*x*	80	1	2	16	42	4	21	22	*y*	*y*		43	0.10
37			52	51	0	0	52	0	48	4					
38	0	0	8	5	0	0	8	0	8	0	3,850	3,850	PM	33	
39			6	6	0	0	5	1	6	0				33	
40	*x*	*x*	5	0	0	0	5	0	3	2	*x*	*x*	0	27	
41			4	3	3		4	0	4	0					
42	*y*	*y*	111	12	*y*	0	106	5	56	55				34.2 62.5	
43	21	21	1	1	0	0	1	0	1	0	4,440	4,440	0	37.7	0.10
44	4	*y*	62	10	7	*y*	62	*y*	*y*	*y*	2,094	*y*		30.9	*y*
45			1	1	0	0	1	0	1	0				39	

[1] *e* indicates "estimated."

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	Brookshire, Hebert and Duhon sands	Mio	Sand	Por	Brookshire Sand 7,860	7,900	40	DS	Oligocene	12,214
2		Mio	Sand	30	1,300	1,350	*y*	SD	Miocene	6,204
3	Bancroft	Eoc	Sand	25	7,360	7,260	60.0	DF	Eocene (Ckf-Yeg.)	8,091
4	Miocene	Mio	Sand		8,204	8,215		DS	Miocene	12,222
5	Miocene	Mio	Sand	Por	10,517 10,900	10,530 10,905	10	D	Miocene	11,871
6	Pliocene	Pli	Sand	Por	1,710	1,720	10	DS	Vicksburg	8,090
7		Mio	Sand	27.5	424 3,198 4,285		32.5	D	L. Oligocene	6,471
8		Mio	Sand		6,820	7,700	20	D	Salt	9,263
9	Marginulina	Olig	Sand		6,386	7,198	20	D	Vicksburg	8,404
10	Miocene	Mio	Sand	Por	5,520	5,643	60	DS	Miocene	10,513
11	Mio-Discorbis and Olig Discorbis	Mio Olig	Sand	*x*	6,500 8,500 9,100	9,200	Mio 80 Olig 8	AF	Marginulina	10,521
12	No. 1 to No. 5 sands	Mio	Sand	25	(No. 3 sand) 4,500	4,600	40	DS	Frio	8,321
13	Discorbis, Heterostegina and Marginulina	Olig	Sand		7,830	9,118	90	D	Vicksburg	10,432
14	Miocene	Mio	Sand	Por	4,510	6,813	90	DS	Miocene	6,813
15		Mio	Sands					SD		
16		Mio	Sand	27	7,200	7,250	17	SD	Miocene	8,311
17	Discorbis	Olig	Sand	Por	8,400	8,950	15	D	Marginulina	11,693
18		Mio	Unconsolidated sands	Por	900 7,200	900 7,200	30	DS SD	Miocene	10,690
19	Cockfield and Sparta	Eoc	Sand	Good	5,650	5,800	50	DS	Wilcox	9,251
20	Miocene	Mio	Sand		2,435	8,396	45	SD	Oligocene	8,969
21		Mio Olig	Sand	Por	8,035	8,045	10	DS	Vicksburg	10,012
22	Miocene	Mio	Sand		5,100	6,640	100	D	Miocene	9,895
23	Heterostegina	Mio, Olig	Sand	Por	7,185	8,788	20	D	Vicksburg	10,632
24										
25	Marine Miocene, Oligocene	Mio Olig	Sand	Por	5,600	8,265	35	DS	Vicksburg	8,445
26	Miocene	Mio	Sand	Por	13,208	13,333	77	AF	Miocene	13,333
27	Miocene	Mio	Sand	Por	3,206	6,842	15	DS	Miocene	7,918
28	Miocene	Mio	Sand	Por	2,750	4,350	*y*	DS	Vicksburg	7,000
29	Marginulina	Olig	Sand	40	9,137	9,139	2	D	Marginulina	13,000
30	Frio	Olig	Sand	30	7,272 7,422	7,760 9,010			Vicksburg	9,010
31	Wilcox	Eoc	Sand	30	8,440	8,570	60	AF	Wilcox	9,181
32	Miocene	Mio	Sand	Por	3,150	8,000	7	DS	Miocene	12,125
33										
34	Miocene	Mio	Sand	Por	4,072	6,993	15	DS	Miocene	7,200
35	Miocene	Mio	Sand	Por	8,880 9,460	8,887 9,518	40	D	Miocene	10,752
36	Miocene-Oligocene	Mio-Olig	Sand	Por	5,156	7,050	50	AF	Vicksburg	9,246
37	Miocene	Mio	Sand	Por	8,500	8,510	10	D	Miocene	12,526
38	Miocene	Mio	Sand	Por	6,118	9,990	30	D	Miocene	10,453
39	Miocene	Mio	Sand		6,700	8,960	270	D	Miocene	9,796
40	Miocene	Mio	Sand	Por		3,500 4,300	40	DS	U. Oligocene	9,545
41	Miocene	Mio	Sand					SD		9,835
42		Mio, Olig	Sand	30	3,100 3,900 4,300 5,900 7,200	8,210	45	SD	Oligocene	8,265
43	Marginulina	Olig	Sand	Por	9,745	9,770	25	DS	Marginulina	10,000
44	Hackberry	Olig	Sand	Por	*y*	*y*		DS	Frio	7,208
45	Oligocene	Olig	Sand	Por	8,570	8,590	20	DS	Oligocene	9,011

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
46	Horseshoe, Bayou, *St. Mary*	1937	200	0	587,561	285,000
47	Houma, *Terrebonne*	Abandoned				
48	Houma, South, *Terrebonne*	1938	100	100	158,723	143,000
49	Iowa, Calcasieu, *Jefferson Davis*	1931	920	920	38,838,000	3,940,000
50	Jeanerette, *St. Mary*	1935	300	50		
51	Jefferson Island, *Iberia*	1938	100	0	170,229	149,000
52	Jennings, *Acadia*	1901	480		67,647,678	4,899,414
53	Jenning, South, *Jefferson Davis*	1934	0	480	0	0
54	Kennilworth, *St. Bernard*	1939	*y*	*y*	8,184	8,184
55	Lafitte, *Jefferson*	1935	2,400	0	18,207,100	4,748,000
56	Lake Barre, *Terrebonne*	1929	340	0	16,120,674	350,000
57	Lafourche Crossing, *Lafourche*	1939			35,725	35,725
58	Lake Hermitage, *Plaquemines*	1934	100	0	142,000	21,000
59	Lake Long, *Lafourche*	1937	2,500*x*	*x*	790,095	431,252
60	Lake Mongoulouis, *St. Martin*	1939	20	0	5,000	5,000
61	Lake Pelto, *Terrebonne*	1929	80	0	1,382,570	389,000
62	Lake Verrett, West, *St. Martin*	1938	80		135,912	130,000
63	Lake Washington, *Plaquemines*	1931	160	0	2,681,000	265,000
64	LaPice, *St. James*	1939	0	*x*	3,602	3,602
65	LaPlace, *St. John the Baptist*	1939		40	(dist.) 4,173	(dist.) 4,173
66	Leesville, *Lafourche*	1931	480	0	20,311,503	1,324,000
67	Lirette, *Terrebonne*	1937	0	300	39,705	6,000
68	Lockport, *Calcasieu*	1924	350	0	14,927,133	376,744
69	New Iberia, *Iberia*	1917	250	0	18,135,664	4,145,000
70	Paradis, *St. Charles*	1939	1,000	0	18,000	18,000
71	Perkins, *Calcasieu*	1939	0	40	0	0
72	Pine Prairie, *Evangeline*	Abandoned				
73	Port Barre, *St. Landry*	1929	300	0	8,146,000	672,000
74	Potash, *Plaquemines*	1937	150	0	133,000	132,000
75	Quarantine Bay, *Plaquemines*	1937	640	0	1,165,038	901,288
76	Raceland, *Lafourche*	1938	60	40	752,302	
77	Roanoke, *Jefferson Davis*	1934	750		8,060,000	900,000
78	Roanoke, South, *Jefferson Davis*	1937	1,200		305,000	270,000
79	St. Martinsville, *St. Martin*	1935	100	0	1,005,880	203,855
80	Sorrento, *Ascension*	1928	100		1,016,185	118,485
81	Starks, *Calcasieu*	1925	60	0	2,921,513	162,803
82	Sulphur Mines, *Calcasieu*	1926	140	0	13,971,000	1,384,000
83	Sweet Lake, *Cameron*	1926	100		4,270,000	373,000
84	Tepetate, *Acadia*	1935	1,200		7,447,362	1,827,510
85	Tepetate, North, *Acadia*	1938	0	1,600	67,325	59,158(*y*)
86	Timbalier Bay, *Lafourche*	1938	60	0	*y*	*y*
87	University, *S. Baton Rouge, E. Baton Rouge*	1938	720	120		
88	Valentine, *Lafourche*	1936	150		3,720,768*e*	1,087,000*e*
89	Venice, *Plaquemines*	1937	100	0	1,163,246	507,304
90	Vermilion Bay, *Iberia*	1939	50	0		
91	Ville Platte, *Evangeline*	1937	1,500		4,109,312	3,305,972
92	Vinton, *Calcasieu*	1910	300		45,022,300	415,475
93	Welsh, *Jefferson Davis*	1902	100	0	637,166	8,969
94	White Castle, *Iberville*	1929	200		3,466,000	630,000
95	Woodlawn, *Jefferson Davis*	1938	200	360	682,000	476,000

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
46			4	2	0	0	4	0	4	0				40	
47															
48	1,257	1,049	2	1	0	0	2	0	2	0	4,800	3,600	0	37.7	0.10
49	27,230*e*	2,800*e*	80	2	0	0	48	0	40	8	3,100	2,925	0	35	0.09
50			23			1	23	1	22	1	2,950			36	
51			4	2	0	0	4	0	4	0				37	
52			649	25	*y*	*y*	158		90	68				23–40	
53	2,809	1,894	3	1	0	0	0	3			3,921	3,921			
54	*y*	*y*	1	1	1	*y*	1	0	*y*	*y*	*y*	*y*		*y*	
55			36	7	0	0	36	0	36	0				36.5	
56			42	1	5	*x*	22	0	9	13				29	
57		98		1	0	0	1		1	0	4,600		0	41	0.065
58	*x*	*x*	4	1	0	1	2	0	0	2	*y*	*y*	0	32.1	0.06
59	*x*	*x*	10	5	0	1	8	2	10	0	4,220–5,060	4,220–5,060	0	39.8	0.10
60			2	2	0	2	0	0	0	0					
61			15	5	*x*	*x*	11	0	11	0				*y*	
62	177	174	2	1	0	0	2	0	2	0			0	37.7	0.10
63	*x*	*x*	13	0	0	0	7	0	7	0	*y*	*y*	0	18	0.73
64	208	208	1	1	0	0	0	1	1	0	6,000	6,000	0	45.6	0.10
65	130	130	1	1	0	1			1			3,800	0	60	
66			120	1			87	0	8	79				*y*	
67	*x*	*x*	7	4	0	4	3	0	3	0	*y*	*y*	0	48	0.34
68			119		1		23	0	0	23				24–40	0.3
69			87	22	5	*x*	65	*x*	42	23				*y*	
70			2	2	0	0	2	0	2	0				51	
71	*x*	*x*	1	1	0			1			*x*	*x*	0		
72															
73			61	7	4	*x*	30	4	5	25				*y*	
74	*x*	*x*	4	3	0	1	3	0	3	0	*y*	*y*	0	28	0.1
75	0	0	16	11	1	0	16	0	16	0	3,247	3,247	PM	35.4	
76	728		5	1	0	0	3	2	3	0	4,667	4,615	0	35.7	
77	7,000*e*	630*e*	35	0	5	4	22		17	5		3,250	0	39	
78	3,050*e*	2,700*e*	7	5	0	0	7	0	7	0	6,000	6,000		44.4	0.10
79		60,170	2	0	0	0	2	0	2	0	2,524	2,524	0	31.4	0.12
80			15	1	1	1	8		6	2	*x*	*y*	0	26–32	0.5
81	*y*	*y*	23	0	1	1	23	1	*y*	*y*	0	0	*y*	*y*	
82	*x*	*x*	120	0	36	24	60	0	5	55	*x*	*x*	0	18–32	0.3–0.5
83	*x*	*x*	11	1	0	0	7	0	5	2	*x*	*x*	0		
84	35,631	9,909	59		1	3	51	2	51		3,640	2,569	PM	34	−0.2
85	2,526	2,180	7	5	1	5	0	2	2		4,000	4,000		50	*y*
86	0	0	2	1	0	0	2	0	2	0	*x*	*x*	PM	29	
87			63	57		0	59	4						36	
88			26	3	2		24		19	6			0	30–38	0.2
89			12	6	1	0	11	0	11	0	3,290	3,290	0	40.1	0.13
90	54	54	1	1	0	0	1	0	1	0				32	
91	10,332	9,140	82	53	1	2	82		82		4,070	2,962	PM	42	−0.1
92	0	0	74	3	2	*y*	74	*y*	*y*	*y*	*y*	*y*		*y*	*y*
93	0	0	17	0	4	0	13	0	*y*	13	*x*	*y*		21	*y*
94	1,700*e*	2*e*	16	3	2	2	8	1	6	2		2,460	0		
95	*x*	*x*	12	8	0	0	12	0	11	1	*x*	*x*	0	33–39	0.01

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
46	Miocene	Mio	Sand	Por	10,863 10,873 Sev. Sds.		40	D	Miocene	12,261
47										
48	Peters	Mio	Sand	30	10,300	10,320	10	DS	Miocene	11,344
49	Various (Sands No. 1 to No. 7)	Mio, Olig	Sand	30	(No. 6 Sd) 6,850	6,950	50	DS	Vicksburg (?)	9,161
50		Mio	Sand					DS		
51	Miocene	Mio	Sand	Por	7,827 8,170	7,837 8,210	40	DS	Miocene	9,458
52	Upper Miocene to Marginulina	Mio, Olig	Sand		1,883	8,230	120	SD	Vicksburg	9,132
53		Mio, Olig	Sand	30	8,600 9,500	8,700 9,518	100 18	D	Oligocene	9,944
54	Oligocene	Olig	Sand	Por	10,595	10,638	*y*	DS	*y*	11,469
55	Miocene	Mio	Sand	Por	8,035	10,130	80	D	Miocene	12,128
56	Miocene	Mio	Sand	Por	3,777	3,836	75	DS	Miocene	11,333
57		Mio			10,127	10,133	6	DS	Miocene	10,511
58	Miocene	Mio	Sand	Por	3,100	3,160	20	DS	Miocene	9,286
59	Miocene	Mio	Sand	Por	9,360	10,430		AF	Miocene	11,347
60	Miocene	Mio	Sand	Por	9,952	9,970	18	DS	Miocene	10,775
61	Miocene	Mio	Sand	Por	1,274 6,248	1,373 6,270	55	DS	Miocene	7,344
62	Miocene	Mio	Sand	30	8,000	8,020	12	DS	Oligocene	11,678
63	Cap rock	Pli	L	Por	1,100	1,160	35	DS	Miocene	6,445
64	Heterostegina	Olig	Sand	25	10,950	11,000	40	DS	Heterostegina	11,314
65	Miocene	Mio	Sands	Por	8,100	8,900	12–32	DS	Miocene	10,175
66	Miocene	Mio	Sand	Por	2,929	6,530	120	DS	Miocene	9,723
67	Miocene	Mio	Sand	Por	8,300	11,610	50	D	Miocene	12,165
68	Miocene	Mio Mid-Olig	Sands					DS	Vicksburg	7,767
69	Pliocene-Miocene	Pli-Mio	Sands	Por	2,760	6,159	50	DS	Miocene	9,968
70	Miocene	Mio	Sand	Por	10,288	10,348	60	DS	Miocene	11,170
71	Frio	Olig	Sand	Por	7,038	7,045	10	D	Cockfield	9,450
72										
73	Mio-olig	Mio	Sand	Por		3,190 4,950	25	DS	Frio	7,213
74	Miocene	Mio	Sand	Por	8,050	8,100	20	DS	Miocene	10,227
75	Miocene	Mio	Sand	Por	7,688	8,559	20	DS	Miocene	10,014
76		Mio	Sand	28	7,170 10,130	7,190 10,220	20 90	DS	Miocene	12,200
77	Nos. 5, 6, 7	Olig	Sand	30	No. 6 Sd. 8,750	8,850	35	DS	Vicksburg	10,750
78	Heterostegina	Olig	Sand	Por	9,700	9,900	20	DS	Marginulina	12,088
79	Miocene	Mio	Sands	30	5,500	5,572	20	DS	Vicksburg	9,646
80		Olig-Mio	Sands	Por	900 4,378	900 4,378	20	SD	Oligocene	8,004
81	Cap rock, Miocene	Mio	DL	Por	1,188	*y*	*y*	DS	Jackson	7,207
82	Various sands	L. Mio, Olig	Sands	35	2,800 5,400			SD	Marg.-Vicksburg	6,000
83	Miocene	Mio	Sands	Por	4,457	4,594	*y*	DS	Miocene	8,928
84	Ortego	Marg, Olig	Sand	Por	8,300	8,328	28	DS	Marginulina	9,447
85	7,900, 8,500, 9,000-ft. sands	Olig	Sand	25	7,900	8,600	20	AF	Oligocene	9,487
86	Miocene	Mio	Sand	Por	5,320	5,340 6,795	15	DS	Miocene	8,722
87		Mio	Sand	30	6,419	6,456	8	AF	Vicksburg	10,367
88	Nine sands	Mio	Sands	Por	3,800– 9,300		5–35	DS	Oligocene	11,001
89	Miocene	Mio	Sands	30	7,070	7,311	46.4	SD	Miocene	10,745
90	Miocene	Mio	Sand	Por	10,131	10,241	110	DS	Miocene	10,622
91	Haas, Tate, Wilcox	Eoc	Sand	Por	9,020	9,080	60	DS	Wilcox	10,909
92	Miocene	Mio	Sand	Por	*y*	*y*		DS	Vicksburg	6,553
93	None	Mio	Sand	30	1,350		7	SD	Oligocene	7,410
94	Wibbert No. 4, No. 8, No. 9 sands	Mio	Sand	Por	6,000	6,500	50	DS	Discorbis	8,777
95	Various sands	Marg.		30	8,100 9,600			Faulted	L. Marginulina or Frio	9,802

In Iberia Parish the Texas Company's State No. B-3, a deep flank test on the Vermilion Bay dome, established commercial production a little below 10,000 ft.—the first oil found on this dome. The California Company's Adams-Rutley No. 1 well, Jefferson Parish, discovered what apparently is a prolific Miocene sand at 8200 ft., opening the Barataria field. This discovery was made in November and it is too early to tell the real importance of this find. A new field was opened in Lafourche Parish, called Lafourche Crossing, by Mikton Oil Company's Martinez No. 2 well. This established Miocene production at a little below 10,000 ft. and gives promise of a good field. In Plaquemines Parish the Humble Oil and Refining Co. opened production on the old Potash dome. Its Orleans Levee Board No. 37 found commercial Miocene oil at 8000 ft. In St. Bernard Parish, within sight of New Orleans, the Vendome Oil Co. found saturated Miocene sand at 10,600 ft. in its Kennilworth No. 1 well. At the close of the year the company was in the process of completing the discovery for commercial production. The Shell Oil Co. is credited with an oil-field discovery in St. James Parish known as La Pice area. Its Schexneyder No. 1 established the presence of commercial production in the Oligocene at about 11,000 ft. Another oil-field discovery near the city of New Orleans is the Pan American's Mill No. 1, in the La Place area, St. John the Baptist Parish. The discovery well is producing gas and a high-gravity oil from the Oligocene at about 8100 ft. There were two new discoveries of oil in St. Martins Parish; namely, the Shell's Iberville Land Company No. 1, called Happytown area, and The Texas Company's St. Martin Land Company No. 1, called the Henderson area. In both it is believed that the producing formation is Oligocene and both give promise of being worth while. Among the more important of the old domes or oil fields that have yielded new producing horizons during the year are Jennings, Ville Platte, Golden Meadows, Charenton and Venice. The full details of these newer finds are not yet available. Southern Louisiana has added, during the year, a very considerable new oil reserve.

ACKNOWLEDGMENTS

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Oil and Gas Development in Michigan during 1939

By Theron Wasson,* Member A.I.M.E.

(New York Meeting, February 1940)

Michigan has had another record year. Its production has been maintained by the development of fields discovered in 1938. Two minor fields were listed as discoveries in 1939. These are in the southwestern part of the state, where the greatest drilling activity took place. During the year 1465 tests were completed, of which 828 were oil wells, 56 gas wells and 581 dry holes. The four southwestern counties—Allegan, Ottawa, Kent and Van Buren—had 1077 tests drilled, while nine other southwestern counties had 70 tests, making a total of 1147 for this part of the state, 78 per cent of all drilled during the year.

Michigan's production of 23,400,000 bbl. during 1939, equal to an average daily production of 64,110 bbl., exceeded 1938 by 4,655,000 bbl., thus establishing another annual record, which brought the cumulative amount for the state to a little over 125,000,000 barrels.

A map showing location of Michigan oil and gas fields was published in the Transactions in 1939 (Vol. 132, p. 353).

Active Oil Fields.—The Walker field, near Grand Rapids, Kent County, had a rapid development during the year. Traverse limestone production was discovered here in September 1938, and development has been rapid during 1939. At the end of the year 5500 acres have been proved by drilling. The Traverse limestone is found in Walker field at a depth of about 1810 ft. The Temple field, Clare County, was the most active in Central Michigan. Its production is from the Monroe dolomite at a depth of 3890 ft. In this field 2500 acres have been proved by 125 producing wells. Michigan's largest producer for 1939 was drilled in the Temple field, with a rated potential of 8760 bbl. per day. The Wise field, Wise township, Isabella County, discovered in 1938, had a steady and orderly development because the operators agreed on a staggered 20-acre spacing program. So far 760 acres have been proved for production from the Dundee limestone, found at 3650 feet.

Active Gas Fields.—The most active areas in which drilling was done during the past year for gas were the Freeman and Lincoln fields in Clare County, the Clayton field of Arenac County, and the Home field of

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Summarized at meeting; manuscript received at the office of the Institute March 8, 1940.

[*] Chief Geologist, The Pure Oil Co., Chicago, Illinois.

TABLE 1.—*Oil and Gas Production in Michigan*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
1	Saginaw, *Saginaw*	1925	1,800	0	1,326,857	23,675	0	0	282	0	0	0	55	0
2	Gratiot, *Gratiot*	1927	0	400	0	0	4	0	3	0	0	0	0	0
3	Muskegon, *Muskegon*	1927	2,700	0	6,617,150	47,950	6,777	92	411	0	10	0	65	16
4	Mt. Pleasant, *Isabella-Midland*	1928	8,000	0	20,733,018	478,968	3,158	387	441	1	24	0	197*y*	0
5	Leaton, *Isabella*	1929	2,100	480	2,611,586	161,716	173	9	90	0	2	0	48	3
6	Clare (Gas), *Clare*	1929	0	400	0	0	642	56	9	0	0	0	0	8
7	Vernon, *Isabella*	1930	1,100	880	3,980,904	190,967	1,270	45	91	0	4	0	39	6
8	Broomfield (Gas), *Isabella*	1930	0	4,100	0	0	5,938	506	54	0	6	0	0	35
9	Porter-Yost, *Midland*	1931	8,340	0	34,906,694	1,928,104	3,852	398	518	1	39	0	349	0
10	Hart, *Oceana*	1932	160	0	116,275	0	0	0	17	0	0	0	0	0
11	Ogemaw, *Ogemaw*	1933	5,000	0	3,657,601	597,834	0	0	251	9	12	0	235	0
12	Edmore, *Montcalm*	1933	160	0	385,865	22,620	0	0	13	0	1	0	7	0
13	Birch Run, *Saginaw*	1934	300	0	170,715	14,515	0	0	28	0	0	0	25	0
14	Six Lakes (Gas), *Mecosta-Montcalm*	1934	0	10,120	0	0	16,572	4,868	242	0	9	0	0	203
15	Beaverton, *Gladwin*	1935	580	0	612,783	57,662	0	0	28	0	3	0	20	0
16	Austin (Gas), *Mecosta*	1935	0	2,200	0	0	6,010	800	29	2	0	0	0	17
17	Crystal, *Montcalm*	1935	2,180	200	6,992,977	123,712	377	46	240	0	18	0	27	6
18	New Haven, *Gratiot*	1935	0	2,400	0	0	1,896	643	51	3	0	0	0	48
19	South Buckeye, *Gladwin*	1936	2,500	0	3,381,318	405,293	0	0	187		25		140	0
20	North Buckeye, *Gladwin*	1936	2,900	0	12,944,586	2,096,475	0	0	262	1	17	0	231	0
21	Ravenna, *Muskegon*	1936	0	4,320	0	0	1,070	297	29	2	1	0	0	28
22	Sherman, *Isabella*	1936	1,270	0	3,149,954	432,771	647	229	87	4	10	0	56	0
23	Clayton, *Arenac*	1936	1,300	560	2,797,473	638,463	292	284	81	20	3	0	51	23
24	Salem, *Allegan*	1937	1,750	0	2,089,065	751,348	0	0	163	61	10	0	146	0
25	Adams, *Arenac*	1937	400	0	120,375	53,617	0	0	15	3	2	0	13	0
26	Bentley, *Gladwin*	1937	1,000	0	412,602	187,260	0	0	37	2	1	0	36	0
27	Edenville, *Midland*	1938	400	0	919,441	315,523	0	0	35	0	0	0	31	0
28	Clare City, *Clare*	1938	0	640	0	0	468	362	6	1	0	0	0	6
29	Monterey, *Allegan*	1938	300	0	278,500	57,476	0	0	25	0	4	0	19	0
30	Dorr, *Allegan*	1938	350	0	210,323	83,001	0	0	24	1	0	0	21	0
31	Home Twp. (Gas), *Montcalm*	1938	0	2,560	0	0	586	534	15	9	0	0	0	15
32	Winfield (Gas), *Montcalm*	1938	0	2,080	0	0	433	352	11	4	0	0	0	7
33	Temple, *Clare*	1938	2,700	0	5,773,507	4,899,825	0	0	134	95	8	0	125	0
34	Freeman (Gas), *Clare*	1938	0	2,560	0	0	74	74	13	11	0	0	0	13
35	Lincoln (Gas), *Clare*	1938	0	1,920	0	0	66	66	8	7	0	0	0	8
36	Diamond Springs, *Allegan*	1938	560	0	575,720	130,246	0	0	55	2	22	0	32	0
37	Wise, *Isabella*	1938	880	0	277,587	268,641	24	24	19	17	0	0	19	0
38	Overisel, *Allegan*	1938	900	0	446,327	303,361	0	0	38	18	10	0	28	0
39	Bloomingdale, *Van Buren*	1938	1,130	0	3,854,984	3,340,876	0	0	158	86	41	0	117	0
40	Walker, *Kent*	1938	6,560	0	2,806,780	2,805,785	0	0	286	285	0	0	286	0
41	Columbia, *Van Buren*	1938	1,000	0	1,196,112	1,194,155	0	0	91	85	4	0	83	0
42	Lake Mill, *Van Buren*	1938	450	0	230,262	222,016	0	0	24	20	7	0	17	0
43	New Salem, *Allegan*	1938	1,080	0	1,313.715	1,313,017	0	0	87	86	1	0	86	0
44	Bangor, *Van Buren*	1939	160	0	77,673	77,673	0	0	10	10	0	0	10	0
45	Wyoming Park, *Kent*	1939	450	0	11,317	11,317	0	0	10	7	3	0	4	0
46	Miscellaneous (scattered)				463,453	166,113	38	38	66	31	5	0	50	0
47	Total		60,460	35,820	125,443,499	23,401,975	50,367	10,110	4,774	884	302	0	2,668	442

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[b] Footnotes to column heads and explanation of symbols are given on page 239.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	0	55	*y*	*y*	0	44.3	0.24	Berea	Mis	S	P	1,820	1,850	16	A	Sylvania	3,970
2	0	0	*y*	*y*	0	0	*y*	Parma	Pen	S	P	500	510	10	MCY	Dundee	3,100
3	0	65	*y*	*y*	0	37.4	0.56	Traverse, Dundee	Dev	L	P	2,050	2,075	10	A	St. Peter	4,754
4	0	197	*y*	*y*	*y*	41.5	0.13	Dundee	Dev	L	P	3,536	3,568	14.6	A	Sylvania	4,821
5	0	48	550	*y*	*y*	43.0	0.16	Stray-Marshall Dundee	Mis Dev	S L	P	1,239 3,644	1,243 3,681	4.0 7.5	A	Monroe	4,390
6	0	0	605	135	0	0	*y*	Stray-Marshall	Mis	S	P	1,408	1,413	5	A	Monroe	4,055
7	0	39	575	*x*	*y*	44.1	0.30	Monroe	Dev	D	P	3,741	3,744	3	A	Monroe	3,907
8	0	0	580	180	0	0	*y*	Stray-Marshall	Mis	S	P	1,300	1,350	5	A	Monroe	3,788
9	1	348	*y*	*y*	*y*	41.3	0.26	Dundee	Dev	L	P	3,422	3,434	12	A	Monroe	4,040
10	0	0	*x*	0	0	34.0	*y*	Traverse	Dev	L	P	1,880	1,890	4	A	Dundee	2,407
11	0	235	*y*	*y*	0	33.4	0.35	Traverse Dundee	Dev	L	P	1,800 2,622	1,810 2,707	5 20	A	Monroe	3,637
12	0	7	900	*y*	0	43.2	0.11	Traverse	Dev	L	P	3,108	3,112	4	A	Monroe	3,700
13	0	25	*y*	*y*	0	42.4	0.25	Berea	Mis	S	P	1,529	1,546	13	A	Dundee	2,760
14	0	0	516	359	0	0	*y*	Stray-Marshall	Mis	S	P	1,275	1,300	16	A	Monroe	3,529
15	0	20	*y*	*y*	0	41.3	0.16	Dundee	Dev	L	P	3,880	3,895	12	A	Dundee	4,025
16	0	0	512	306	0	0	*y*	Stray-Marshall	Mis	S	P	1,390	1,410	10	A	Monroe	4,042
17	0	27	G448	G404	0	41.3	0.37	Stray-Marshall Monroe	Mis Dev	S L	P	1,016 3,191	1,021 3,202	4 4	A	Monroe	3,520
18	0	0	448	382	0	0	*y*	Stray-Mar	Mis	S	P	950	915	5	A	Dundee	3,657
19	0	140	*y*	*y*	*y*	39.0	0.25	Dundee	Dev	L	P	3,574	3,597	11	A	Monroe	4,330
20	0	23	*y*	*y*	*y*	39.0	0.25	Dundee	Dev	L	P	3,621	3,647	11	A	Monroe	4,696
21	0	0	720	*y*	0	0	*y*	Berea	Mis	S-D	P	1,212	1,233	10	*y*	Dundee	2,306
22	1	55	*y*	*y*	0	47.8	*y*	Monroe	Dev	D	P	3,648	3,652	4	A	Monroe	4,031
23	0	51	620	520	0	34.3	*y*	Berea Dundee	Mis Dev	S D	P	1,166 2,534	1,189 2,576	12 12	A	Dundee	2,707
24	*y*	146	*y*	*y*	0	41.5	*y*	Traverse	Dev	L	P	1,587	1,601	8	A	Dundee	1,950
25	0	13	*y*	*y*	0	T. 37.0 D. 34.3	*y*	Traverse Dundee	Dev	L	P	2,020 2,809	2,039 2,964	15 16	A	Dundee	2,964
26	0	36	*y*	*y*	0	41.4	*y*	Dundee	Dev	L	P	3,500	3,536	25	A	Dundee	3,685
27	0	31	*y*	*y*	0	41.3	*y*	Dundee	Dev	L	P	3,788	3,796	8	A	Dundee	4,015
28	0	0	605	480	0	0	*y*	Stray-Marshall	Mis	S	P	1,283	1,293	6.5	A	Monroe	3,865
29	0	19	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,638	1,647	3	A	Traverse	1,808
30	0	21	*y*	*y*	0	41.1	0.44	Traverse	Dev	L	P	1,596	1,607	4	A	Monroe	2,065
31	0	0	515	470	0	0	*y*	Stray-Marshall	Mis	S	P	1,390	1,400	7.5	A	Monroe	3,665
32	0	0	446	431	0	0	*y*	Stray-Marshall	Mis	S	P	1,124	1,141	8	A	Monroe	3,374
33	43	82	*y*	*y*	0	43.8	0.37	Monroe	Dev	D	P	3,895	3,898	4.5	A	Monroe	3,924
34	0	0	607	603	0	0	*y*	Stray-Marshall	Mis	S	P	1,486	1,512	12	A	Monroe	3,956
35	0	0	607	603	0	0	*y*	Stray-Marshall	Mis	S	P	1,526	1,538	10	A	Monroe	4,285
36	0	32	*y*	*y*	0	*y*		Traverse	Dev	L	P	1,466	1,472	3.5	A	Traverse	1,571
37	0	19*y*	*y*	*y*	0	43.0	*y*	Dundee	Dev	L	P	3,702	3,716	10.5	A	Dundee	3,723
38	0	28	*y*	*y*	0	41.7	*y*	Traverse	Dev	L	P	1,471	1,481	3	A	Traverse	1,690
39	0	117	*y*	*y*	0	41.2	0.79	Traverse	Dev	L	P	1,216	1,219	2.5	A	Monroe	1,904
40	186*y*	100*y*	*y*	*y*	0	41.0	*y*	Traverse	Dev	L	P	1,827	1,848	6	A	Monroe	2,400
41	0	83	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,190	1,193	2.5	A	Monroe	1,904
42	0	17	515	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,277	1,279	1.5	A	Monroe	1,820
43	0	86	*y*	*y*	0	41.0	*y*	Traverse	Dev	L	P	1,6[illegible]	1,631	6	A	Monroe	1,968
44	0	10	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,002	1,006	2	A	Traverse	1,050
45	0	4	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,191	1,218	6	A	Dundee	2,255
46	0	50															
47	231	2,437															

Montcalm County. All new developments are from the Michigan stray sand except the Clayton field, which is from the Berea sandstone. Gas from the Berea at 1100 ft. in the Walker field near Grand Rapids should be reported as one of the new gas discoveries of the year.

Wildcat Drilling.—Wildcat tests were drilled in 41 counties of the state during the year. Allegan, Barry, Van Buren, Cass and others in the southwestern area accounted for most of the 408 tests that were classed as wildcats. A test of special interest was drilled in sec. 2, Monitor township, Bay County, to a depth of 4454 ft. It had shows of oil in the Traverse, Dundee, and Monroe and found high-grade oil in the Sylvania sandstone of Lower Devonian age at 3960 ft. It failed to produce when deepened, so it was plugged back to the Monroe at 3520 ft., to make a small well.

Exploration.—Reflection-seismograph and gravity surveys were made in the central basin and the southwestern area, and shallow drilling for structural markers below the glacial drift continued throughout the year.

TABLE 2.—*Summary of Drilling Operations in Michigan*

Important Wildcats Drilled in 1939

County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day, Bbl.	Remarks
	Survey	Lat.	Long.					
1. Barry....	27	2 N	9 W	1,941	Traverse	N. A. Trexler	15	High well, demonstrating structural possibilities which will be tested during 1940
2. Bay......	2	14 N	4 E	4,454	Sylvania	Gulf Refining Co.	34	Showed oil in Dundee and Lower Monroe in commercial quantities and reported very strong showing high gravity oil in Sylvania
3. Berrien...	10	4 S	18 W	2,711	St. Peter	Sprenger Brothers	0	First St. Peter test in area
4. Clare.....	28	20 N	6 W	3,912	Monroe	Daily Crude Oil Co.	0	High well, demonstrating important structural possibility
5. Gladwin..	10	18 N	2 W	3,953	Dundee	Sun Oil Company	0	High well, indicating new structural possibility—showed oil
6. Gladwin..	11	18 N	1 W	4,696	Monroe	J. V. Wicklund Dev. Co.	0	First deep test on N. Buckeye structure drilled 1162′ below top of Dundee but did not reach Sylvania
7. Kent.....	14	6 N	12 W	2,255	Monroe	Freeland & Rogers	17	Discovery well Wyoming Park field
8. Monroe...	30	6 S	6 E	2,126	Trenton	A. V. Oil & Gas Co.	108,000 cu. ft. gas	Stimulated Trenton prospecting in area
9. Monroe...	19	6 S	6 E	2,162	Trenton	A. V. Oil & Gas Co.	140	First commercial Trenton production in state
10. Oceana...	15	16 N	16 W	1,930	Traverse	Teater Oil Co.	0	Revival of interest in interesting area northeast of the abandoned Hart pool
11. Osceola...	8	17 N	10 W	3,568	Monroe	Weber Oil Co.	Show	High well, demonstrating structural possibilities
12. Van Buren	29	2 S	16 W	1,008	Traverse	Blood & Hendershott	400	Discovery well Bangor field

	In Proven Fields	Wildcats
Number of wells drilling December 31, 1939....................	67	24
Number of oil wells completed during 1939....................	817	11
Number of gas wells completed during 1939....................	56	0
Number of dry holes completed during 1939....................	196	385

Conservation and Proration.—A conservation law for Michigan was passed early in the year, establishing State control of its oil and gas fields. A Director of Conservation, appointed by the Governor, set up an Advisory Board of six members chosen from the companies operating in the state. The first order of the Board became effective June 1 and established a 10-acre minimum drilling pattern and daily allowables for the new fields. Two other orders were issued during the year, which changed the allowables in some fields.

Drilling.—Fields in Michigan are still being drilled with cable tools. Experiments started last year with the rotary method in the Temple field have been discontinued.

Prices.—Prices of oil rose slightly during the year with moderate fluctuations from the low of December 1938.

ACKNOWLEDGMENTS

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Oil and Gas Development in Mississippi during 1939

By H. M. Morse*

(New York Meeting, February 1940)

Tinsley Oil Field.—Mississippi joined the oil-producing states when on Sept. 13, 1939, the Union Producing Company's G. C. Woodruff well No. 1, sec. 13, T. 10 N., R. 3 W., Yazoo County, was completed after drilling plug at 4540 ft. in the Woodruff sand of the Eutaw formation of Cretaceous, producing 300 bbl. per day of 34.4° gravity oil through a ¼-in. choke, with a gas-oil ratio of 80 to 1 and bottom-hole pressure of 2045 lb. This was the discovery well in the Tinsley oil field. The well was drilled to a total depth of 4567 ft. and no salt water was encountered. The sand underlies the Selma chalk formation.

Nine producing oil wells and one dry hole were drilled and completed by the end of 1939. Two producing sands have been found in the Eutaw and a third sand in the top of the Tuscaloosa formation, called the Woodbine sand in Louisiana and Texas. Faulting is an important factor in the Tinsley field.

Total oil production has been approximately 250,000 bbl. from the nine flowing wells. Total depth to top of productive zone was 4540 ft.; to bottoms of productive wells, 4580 ft. Net thickness of the producing formation is 20 to 40 ft., and its porosity is 24 per cent. The deepest zone tested was the Tuscaloosa, in which the depth of hole was 6112 feet.

Six hundred and forty acres has been proved for oil production.

Jackson Gas Field.—The Jackson gas field has shown a steady decline in the number of wells but the pressure has been maintained. This field is a perfect example of a water-driven field and the time of wells going to salt water is predictable. Five wells were drilled in the Jackson field, of which only one produced.

Amory Gas Field.—Interest was renewed in the Amory gas field, where a new well was started in the fall of 1939.

Geological Formations.—The deepest well drilled in 1939 was the Willmut Gas and Oil Company's Cleve Love S. F. Johnson No. 1, sec. 29, T. 6 N., R. 1 W., Hinds County. This well encountered the Lower Cretaceous, Trinity series from 3770 to 6422 ft.; Lower Mesozoic from 6422 to 6484 ft. The geological correlations and nomenclature of the formations in Mississippi are shown in the accompanying stratigraphic section.

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* State Oil and Gas Supervisor, Jackson, Mississippi.

General Stratigraphic Section

Era	System	Series	Group	Formation Member
Cenozoic	Quaternary	Recent		Alluvium
		Pleistocene		Alluvial terrace deposit Port Hudson F.M. and Loess terrace deposit
	Tertiary	Pliocene		Citronelle
		Miocene	Grand Gulf	Pascagoula clay Hattiesburg clay Catahoula sand Chickasawhay Bucatunnia
		Oliogocene	Vicksburg	Byram marl Glendon lime Marianna mint spring marl Forest Hills sand Red Bluff clay
		Eocene	Jackson	Yazoo clay Moodys marl
			Claiborne	Yegua Lisbon $\begin{cases}\text{Wautubbee marl}\\\text{Kosciusko sand}\\\text{Winona sand}\end{cases}$ Tallahatta
			Wilcox	Hatchetigbee Bashi Holly Springs Ackerman
			Midway	Nahoela Porters Creek Clayton
Mesozoic		Upper Cretaceous	Gulf	Owl Creek and Prairie Bluff Ripley—McNary sand Selma—Coffee sand Eutaw—Tombigbee Tuscaloosa
Paleozoic		Pennsylvanian Mississippian Silurian Ordovician		Pottsville

The deepest well drilled stratigraphically was in Lafayette County, the Adams Oil and Gas Company's Llewellen No. 1, sec. 9, T. 10 S., R. 1 W., total depth 4184 ft. The Pennsylvanian was encountered from 1845 to 2409 ft.; Upper Mississippian (Chester) from 2409 to 2610 ft.; Lower Mississippian from 2610 to 3689 ft.; Silurian from 3609 to 3774 ft.; and the Ordovician from 3774 to 4184 feet.

Exploration.—Various types of geophysical crews were active toward the close of 1939 in Mississippi. At one time 53 separate crews were operating in the state, especially in the western part. Reflection seismographs encountered some trouble in the Loess formation but this is believed to have been overcome by deeper drilling beneath gravel beds.

Spacing.—The State Oil and Gas Board promulgated a 40-acre spacing rule in the Tinsley oil field as an aid to the operators and land owners. Originally 1600 ft. of surface casing was required but this has been reduced to 600 ft. as a minimum, since the gas pressure was found not to be excessive.

Prospect for 1940.—A considerable increase in drilling is expected in 1940 over 1939, since the Tinsley oil field is in the early stages of its development and a number of blocks have been taken calling for wells to be drilled within the year.

TABLE 1.—*Summary of Drilling Operations in Mississippi*

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		
1	Hinds....	29	6 N	1 W	6,484	Jackson	Lower Mesozoic (?)	Cleve Love et al.	0	0	0	Dry hole
2	Lafayette.	9	10 S	1 W	4,184	Wilcox	Silurian	Adams Oil & Gas Co.	0	0	0	Dry hole
3	Madison..	12	8 N	1 W	6,265	Vicksburg	Woodbine Tuscaloosa	Union Producing Co.	0	0	0	Oil show but dry hole
4	Yazoo....	13	10 N	3 W	4,560	Jackson	Blossom(?) Woodruff sand Eutaw	Union Producing Co.	300 in 24 hr.	80–1	¼	Discovery oil well in Mississippi

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939..................................	9 oil 1 gas	10
Number of oil wells completed during 1939..............................	9	
Number of gas wells completed during 1939..............................	1	
Number of dry holes completed during 1939..............................	4 gas 1 oil	8

Development of Oil and Gas in Missouri in 1939

By Frank C. Greene*

(New York Meeting, February 1940)

Drilling in Missouri in 1939 was marked by wildcatting in the northern half of the state. The total completions numbered 82, exactly half the 164 of 1938. There were 15 gas wells with an initial open flow of 6,383,150 cu. ft., 4 oil wells with about 40 bbl. initial production, and 63 dry holes.

Table 1.—*Wells Drilled for Oil and Gas in Missouri in* 1939

County	Gas Wells	Gas, Cu. Ft.	Oil Wells	Oil, Bbl.	Dry	Drilled below Top of Mississippian
Adair					3	3
Andrew					3	3
Bates	1	50,000			1	1
Cass	2	480,000	4	40[a]	3	1
Carroll					4	
Chariton					1	1
Clay	2	300,000			5	2
Clinton	1	1,904,150			1	2
Daviess					1	1
Harrison					1	1
Henry					1	1
Holt					1	1
Jackson	6	443,000			22	
Johnson					3	2
Livingston					1	1
Platte	3	3,206,000			6	1
Putnam					2	2
Ray					2	
Sullivan					1	1
St. Charles					1	1
Totals	15	6,383,150	4	40[a]	63	25

[a] Production estimated.

The wildcatting followed the widely publicized leasing activity in the Forrest City Basin in northwestern Missouri, northeastern Kansas, southeastern Nebraska and southwestern Iowa. It is worth noting that

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the first discovery of oil was near the center of the leased area near Falls City, Nebraska.

The results of wildcatting in Missouri were a new gas pool in Platte County, in a Pennsylvanian sand, and showings of oil at a number of horizons below the Pennsylvanian. Of the completions, 25 were drilled into Mississippian and older beds, and 19 of these were drilled into beds that are the equivalent of the Arbuckle limestone of Ordovician age of Kansas and Oklahoma. The 25 wells represented 39,178 ft. of hole, an average of 1567 ft. per well.

At the close of the year, wells were drilling or shut down in Buchanan, DeKalb, Holt, Platte (2), Mercer, Adair (2), Knox, and Schuyler (2).

In the southeastern part of the state operations had been started during the year in Bollinger, Butler, and Wayne Counties. No completions, however, were reported.

Oil and Gas Development in New Mexico in 1939

By A. Andreas*

(New York Meeting, February 1940)

New Mexico, after several years as the sixth ranking oil-producing state, was surpassed by Illinois and for 1939 ranks seventh in the United States. Oil production for 1939 was 36,746,840 bbl. Production for 1938 was 35,510,176 bbl., a gain of 0.033 per cent. Production for the year would have been greater had there been a pipe-line outlet for the Vacuum field. The complete shutdown during the latter part of August covering a period of 15 days meant a production loss of over 1,500,000 bbl. of oil.

Daily production allowable as set by the Oil Conservation Commission has followed very closely the recommendations of the Bureau of Mines. It has been found that the recommended allowables as quoted by the Bureau of Mines do not always reflect the actual demand, as there is a considerable lag between the recommended amounts and the current demands.

During the year the various operating companies have done considerable remedial work in setting packers to reduce the gas-oil ratios in the various fields.

Six new fields were discovered in New Mexico during 1939; three in Lea County, two in Eddy County and one in Chaves County.

In the early part of 1939 a committee composed of the various engineers and geologists recommended subdividing the old Artesia area into various producing pools. This division was accepted, therefore the total number of producing fields in New Mexico is considerably greater than the number of fields in 1938, but does not represent new fields discovered during the year.

The southeastern area continues to be the largest producer of oil. During the year 2,716,551 bbl. were produced in Eddy County and 33,690,996 bbl. in Lea County. Total production in the northwestern part of the state, which includes San Juan and McKinley Counties, was 338,293 bbl. At the beginning of the year the daily average nonmarginal well allowable for Lea County was 48 bbl. At the close of the year it was 49 bbl. The daily average production for the year was 97,313 bbl. During the year, 659 wells were drilled in the state, of which 565 were producing oil wells, 15 gas wells, 6 carbon dioxide gas wells and 73 dry holes.

Summarized at meeting; manuscript received at the office of the Institute March 18, 1940.

* State Geologist, member of New Mexico Oil Conservation Commission, Santa Fe, New Mexico.

TABLE 1.—*Oil and Gas Production in New Mexico in* 1939

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Artesia, *Eddy*	1923	6,280	160	4,320,800	166,627
2	Aztec, *San Juan*	1924	90	5	37,322	3,593
3	Barber, *Eddy*	1936	340	0	44,511	16,622
4	Black River, *Eddy*	1937	80	0	2,872	0
5	Blanco, *San Juan*	1927	0	40	1,329	37
6	Comanche, *Chaves*	1936	80	0	1,500*y*	500*y*
7	Cooper, *Lea*	1929	4,000	160	10,909,068	1,379,601
8	Corbin, *Lea*	1938	40	0	1,369	1,369
9	Eaves, *Lea*	1929	720	160	1,064,436	295,587
10	Eunice, *Lea*	1928	20,000	160	40,363,282	7,891,771
11	Getty, *Eddy*	1928	240	0	353,177	11,371
12	Grand Plains, *Chaves*	1939	80	0	500*y*	500*y*
13	Grayburg-Jackson, *Eddy*	1936	5,080	80	6,996,997	1,737,810
14	Halfway, *Lea*	1939	80	0	0	0
15	Hardy, *Lea*	1935	4,600	0	2,053,877	1,048,814
16	High Lonesome, *Eddy*	1939	80	40	430	430
17	Hobbs, *Lea*	1928	10,080	0	89,993,293	4,449,808
18	Hogback, *San Juan*	1922	160	0	1,953,636	71,254
19	Hospah, *McKinley*	1927	160	0	32,065	19,565
20	Jal, *Lea*	1927	1,360*y*	480	5,935,995	206,955
21	Kutz Canyon, *San Juan*	1927	0	2,200	0	0
22	Langlie, *Lea*	1927	5,160	440	3,778,576	1,763,206
23	Leonard, *Eddy*	1929	920	400	728,434	166,439
24	Loco Hills, *Eddy*	1939	2,800	0	330,870	330,870
25	Lynch, *Lea*	1929	440	0	5,731,934*y*	182,010
26	Lynn, *Lea*	1929	1,200	120	677,484	271,593
27	Maljamar, *Lea*	1926	1,240	0	1,382,720	371,514
28	Mattix, *Lea*	1936	5,440	240	3,001,763	1,480,892
29	McMillan, *Eddy*	1938	40	0	294*y*	294
30	Monument, *Lea*	1934	19,720	40	31,942,879	7,739,445
31	North Lynch, *Lea*	1929	80	0	1,012,052*y*	12,052
32	North Maljamar, *Lea*	1939	40	0	826	826
33	Penrose, *Lea*	1935	6,720	0	4,169,803	1,619,873
34	Rattlesnake, *San Juan*	1924	640	0	4,284,067	218,380
35	Red Lake, *Eddy*	1924	1,160	680	263,411	86,327
36	Red Mountain, *McKinley*	1935	20	0	3,900*y*	200*y*
37	Rhodes, *Lea*	1928	280	360	195,907	35,159
38	Robinson, *Eddy*	1926	440	40	245,428	112,138
39	Shugart, *Eddy*	1938	560	0	95,553	87,623
40	Skaggs, *Lea*	1936	120	0	27,615*y*	27,615
41	Skelly, *Lea*	1936	2,360	120	1,560,418	520,979
42	South Eunice, *Lea*	1930	4,000	200	3,304,361	1,301,810
43	South Lovington, *Lea*	1938	1,320	40	178,997	178,997
44	South Maljamar, *Lea*	1939	40	0	0	0
45	Table Mesa, *San Juan*	1925	100	0	503,990	25,264
46	Ute, *San Juan*	1923	0	640	0	0
47	Vacuum, *Lea*	1929	10,800	0	3,728,331	2,867,802
48	West Eunice, *Lea*	1928	200	0	61,392*y*	43,318
	Total		1,190,065	6,805	231,277,464*y*	36,746,840*y*

[b] Footnotes to column heads and explanation of symbols are given on page 239.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]
				During 1939		End of 1939			Number of Wells				
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[e]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	
1	*y*	*y*	159*y*	0	2	0	159	4*y*	56	103	*y*	*y*	0
2	0	0	30	0	1	0	16	0	0	16	*x*	0	0
3	0	0	9	1	0	5	4	0	0	4	*x*	*x*	0
4	0	0	2	0	0	2	0	0	0	2	0	0	0
5	227	32	1	0	0	0	0	1	0	0	1,200	1,000	0
6	0	0	2	1	1	0	2	0	0	2	0	0	0
7	94,154	19,684	104	3	0	10*y*	94	2	46	GL 28 P 20 } 48	1,398	*x*	PM
8	0	0	1	0	0	0	1	0	0	1	*x*	*x*	0
9	6,372	1,034	22	0	0	1	20	1	11	GL 8 P 1 } 9	*x*	*x*	SR
10	173,902	46,326	503	15	0	7	492	4	453	GL 23 P 16 } 39	1,400	*x*	PM
11	0	0	9	0	0	7	2	0	0	2	0	0	0
12	0	0	2	2	0	0	2	0	0	P 2	0	0	0
13	*y*	*y*	135	22	4	0	125	0	*y*	*y*	0	0	0
14	0	0	2	2	4	0	2	0	0	P 2	*x*	*x*	0
15	7,703	3,080	115	36	0	8	107	0	91	P 16	1,400	*x*	0
16	0	0	3	3	0	0	2	1	0	P 2	*x*	*x*	0
17	195,126	9,012	266	0	0	4	248	0	221	GL 12 P 15 } 27	1,550	*x*	SR
18	0	0	7	0	0	0	7	0	7	0	215	135	0
19	0	0	6	1	0	0	6	0	0	6	*x*	*x*	0
20	26,884	1,001	46	0	0	*y*	24	12	2*y*	GL 11 P 11 } 22	*x*	*x*	SR
21	8,773	1,869	15	3	0	0	0	15	0	0	565	435	0
22	21,933	7,762	141	35	1	*y*	125	11	121	GL 1 P 3 } 4	1,450	*y*	RP
23	*y*	*y*	24	7	1	*y*	23	10	*y*	*y*	*y*	*y*	0
24	*y*	*y*	70	70	3	0	70	0	*y*	*y*	800*y*	800*y*	0
25	0	0	16	0	5	0	11	0	0	P 11	1,295	0	0
26	2,347	700	33	5	0	0	26	2	23	GL 1 P 2 } 3	1,365	*y*	SR
27	*y*	*y*	39	13	0	0	31	2	20	11	*y*	*y*	0
28	11,029	6,051	149	60	0	0	136	0	108	28	*x*	*x*	0
29	0	0	3	0	0	0	1	0	0	1	0	0	0
30	94,619	26,403	500	18	0	0	493	0	486	7	1,427	*x*	0
31	0	0	2	0	0	0	2	0	0	P 2	0	0	0
32	0	0	1	0	0	0	1	0	1	0	0	0	0
33	17,944	8,188	168	30	1	0	168	0	150	18	*x*	*x*	0
34	0	0	74	12	11	2	37	0	0	37	275	40	SR
35	*y*	*y*	20*y*	9	11	0	12	8	6	6	*y*	*y*	0
36	0	0	7	0	1	4	2	0	0	2	0	0	0
37	21,148	7	26	3	0	0	7	18	7	0	1,397	*y*	0
38	0	0	15	4	1	0	9	0	6	3	0	0	0
39	0	0	20	9	6	0	14	0	4	10	0	0	0
40	115*y*	115*y*	3	0	0	0	3	0	3	0	0	0	0
41	3,627	1,527	68	16	0	0	59	1	50	9	1,420	*y*	0
42	10,550	5,166	103	32	0	0	100	0	87	13	1,455	*y*	0
43	241	241	34	30	0	0	33	1	30	3	1,670	*y*	0
44	0	0	1	0	3	0	1	0	0	1	0	0	0
45	0	0	7	1	0	0	7	0	0	7	0	0	0
46	5,481	676	3	0	0	0	0	3	0	0	720	470	0
47	4,527	3,591	301	138	4	0	270	0	245	GL 5 P 20 } 25	1,630	*y*	0
48	0	0	5	2	1	0	5	0	0	P 5	1,300	*y*	0
	706,752*y*	142,465*y*	3,272*y*	583*y*	61	50*y*	2,959	96*y*	2,234*y*	509*y*			

TABLE 1.—(*Continued*)

	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
Line Number	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	29.5	0.002	San Andres	Per	LS	x	1,823	2,005		AM	San Andres Per	4,035
2	55	0.01	Farmington sand	CreU	S	x	750	1,075	25	S	Lewis Shale CreU	2,665
3	20.5	0.001	Capitan	Per	L	x	1,459	1,466	7	A	Capitan Per	1,953
4	39	0.001	Delaware sand	Per	S	x	x	2,545	x	MF	Delaware Per	2,885
5	54	0.13	Mesa Verde Pictured Cliffs	CreU	S	x	4,250	4,550	5	H	Mesa Verde CreU	4,550
6	28.5	0.001	San Andres	Per	S	x	x	1,283	x	ML	Capitan Per	1,400
7	29	0.001	White lime	Per	D	Cav	3,542	3,608	x	A	L. San Andres Per	[5,095
8	30.5	0.001	White lime and sand	Per	LS	x	x	4,319	x	A	San Andres Per	5,118 PB 4,319
9	28.5	0.002	Permian sand	Per	S	x	3,175	3,300	x	A	San Andres Per	3,542
10	35.1	0.002	White lime	Per	D	Cav	3,800	3,883	x	A	San Andres Per	4,404
11	24	0.001	Capitan	Per	L	x	1,365	1,380	15	A	Permian	6,683
12	29	0.001	San Andres	Per	S	x	1,305	1,362		A	San Andres Per	1,018
13	27	0.001	Permian sand and white lime	Per	S	x	3,779	3,827		A	San Andres Per	4,383
14	28.6	0.001	White lime	Per	LS	x	x	2,629	x	A	San Andres Per	4,005
15	32.5	0.002	Permian sand and white lime	Per	SD	Cav	3,710	3,763	x	A	San Andres Per	3,872
16	36.2	0.003	Sand	Per	LS	x	1,803	1,824	21	A	San Andres Per	2,265
17	35.4	0.001	White lime	Per	D	Cav	4,050	4,174	123	A	San Andres Per	4,500
18	60	0.001	Dakota sand	CreU	S	x	705	714	9	D	McElmo CreL	1,225
19	29.7	0.025	Hospah sand	CreU	S	x	1,640	1,651	11	DF	Dakota CreU	3,282
20	36	0.002	White lime	Per	D	Cav	3,303	3,334	30	A	San Andres Per	4,125
21			Pictured Cliffs	CreU	S	x	1,840	1,900	60	H	Mesa Verde CreU	4,400
22	28	0.001	Permian sand	Per	S	x	3,350	3,530	x	A	San Andres Per	4,385
23	28.5	0.001	Permian sand and White lime	Per	S	x	2,859	2,950	x	A	San Andres Per	3,507
24	33	0.001	Permian sand	Per	S	x	2,415	2,900	x	A	San Andres Per	3,556
25	30	0.001	White lime	Per	D	Cav	3,760	3,777	x	A	San Andres Per	4,046
26	33	0.001	Permian sand and White lime	Per	D	Cav	3,550	3,797	x	A	San Andres Per	5,095
27	32	0.001	White lime	Per	L	x	4,103	4,145	x	A	San Andres Per	4,390
28	32	0.001	Permian sand	Per	S	x	3,500	3,559	x	A	San Andres Per	4,200
29	27	0.001	Carlsbad	Per	S	x	1,150	1,180	x	A	San Andres Per	3,305
30	35	0.001	White lime	Per	D	Cav	3,829	3,939	x	A	San Andres Per	4,534
31	30	0.001	White lime	Per	D	Cav	3,760	3,777	17	A	San Andres Per	4,046
32	31	0.001	White lime	Per	D	x	3,875	4,015	x	A	San Andres Per	4,097
33	34	0.001	Permian sand	Per	S	x	3,550	3,667	x	A	San Andres Per	4,705
34	60	0.001	Dakota	CreU	S	x	784	808	24	AF	Mississipian	7,370
35	29	0.001	Carlsbad	Per	S	x	1,904	1,930	26	A	San Andres Per	2,905
36	42	0.001	Mesa Verde	CreU	S	x	438	457	13	AF	Mesa Verde CreU	640
37	33	0.001	Permian sand	Per	S	x	3,050	3,375	x	A	San Andres Per	4,115
38	31	0.001	Permian sand and White lime	Per	S	x	3,919	4,009	x	A	San Andres Per	4,359
39	33	0.001	Permian sand	Per	S	x	3,454	3,775	x	A	San Andres Per	4,340
40	30	0.001	White lime	Per	L	x	3,800	3,860	x	A	San Andres Per	4,757
41	32.5	0.001	Permian sand	Per	S	x	3,525	3,663	x	A	San Andres Per	4,052
42	29.5	0.001	White lime	Per	D	Cav	3,775	3,845	x	A	San Andres Per	6,202
43	33	0.001	White lime	Per	L	x	4,730	5,112	x	A	San Andres Per	5,302
44	33.5	0.001	White lime	Per	L	x	4,120	4,152	x	A	San Andres Per	4,383
45	56.5	0.001	Dakota sand	CreU	S	x	1,325	1,337	7	A	Chinlee TriassicU	3,010
46			Dakota sand	CreU	S	x	2,285	2,350	60	D	Dakota Sand CreU	2,350
47	33.5	0.001	White lime	Per	D	Cav	4,418	4,688	200y	A	San Andres Per	5,329
48	31	0.001	White lime	Per	L	x	3,793	3,867	x	A	San Andres Per	4,695

SOUTHEASTERN NEW MEXICO

Lea County.—The Eunice field was the largest producing pool in Lea County with a production of 7,891,771 bbl. from 492 wells, followed by the Monument field with 7,739,445 bbl. from 493 wells. The Vacuum pool was the most active area in New Mexico, with 138 completions.

The discovery well in the South Maljamar field was the Barefield and Brooks well drilled in the SE¼ NE¼, sec. 5, T. 18 S., R. 32 E. The total depth of this well was 3724 ft., and it flowed at a rate of 50 bbl. in 6 hr. This production came from the San Andres formation of Permian age.

The discovery well in the North Maljamar field was the Carper Drilling Company's Taylor No. 1 in the SW¼ SW¼ sec. 30, T. 16 S., R. 32 E. This well encountered production in the San Andres lime at a total depth of 4097 ft. with an initial production of 15 bbl. daily.

The discovery well of the Halfway pool was the Westlea State No. 1 in the NE¼ SW¼ sec. 16, T. 20 S., R. 32 E. swabbing 1000 bbl. of oil daily from the San Andres formation at a depth of 2629 feet.

TABLE 2.—*Summary of Drilling Operations in New Mexico*

Surface Formation, Tertiary; Deepest Horizon Tested, Permian

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Drilled by	Initial Production per Day		Choke or Bean, In.	Pressure, Lb. per Sq. In.	
		Sec.	Twp.	Rge.			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing
1	Chaves	21	11 S	30 E	3,435	Nay Hightower	[1]				
2	Chaves	29	11 S	25 E	1,018	New, Russel & Wood	7	0	P	y	y
3	Chaves	15	11 S	26 E	1,386	Comanche Drilling Co.	[1]				
4	Chaves	17	15 S	27 E	1,963	M. F. Anderson	[1]				
5	Chaves	15	11 S	26 E	1,343	Comanche	7	0	P	y	y
6	Chaves	27	10 S	30 E	4,020	Western Minerals	[1]				
7	Eddy	17	16 S	29 E	1,824	P. H. Nolen	80	0	P	y	y
8	Eddy	19	20 S	31 E	2,458	Culbertson & Irwin, Inc.	[1]				
9	Eddy	20	19 S	29 E	2,215	Henry Swift	[1]				
10	Eddy	4	18 S	25 E	1,050	Farmer & Talmadge	[1]				
11	Eddy	18	23 S	26 E	1,917	Geo. L. Roundey	[1]				
12	Eddy	25	21 S	27 E	628	A. W. Rutter	[1]				
13	Eddy	30	18 S	26 E	2,291	Fred Turner	[1]				
14	Eddy	3	18 S	23 E	1,079	E. S. McAuliffe	[1]				
15	Eddy	7	20 S	31 E	2,515	Stanolind Oil Co.	[1]				
16	Eddy	23	26 S	30 E	4,051	Barnett Oil Co.	[1]				
17	Eddy	6	18 S	30 E	2,874	Martin Yates	520	y	2	y	
18	Lea	30	14 S	38 E	5,512	Fred Turner Jr.	[1]				
19	Lea	34	16 S	34 E	5,690	Magnolia	[1]				
20	Lea	7	25 S	38 E	3,940	Harry Leonard	[1]				
21	Lea	16	20 S	32 E	2,629	Westlea Oil Co.	1,000	0	P	y	y

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	98	20
Number of oil wells completed during 1939	560	5
Number of gas wells completed during 1939	15	0
Number of dry holes completed during 1939	52	21

[1] Dry and abandoned.

Eddy County.—Loco Hills, the scene of the greatest activity in Eddy County, was discovered by the drilling of the Yates et al. Yates No. 1 in the SE¼ sec. 6, T. 18 S., R. 30 E. This well was completed in February at a total depth of 2874 ft., flowing 520 bbl. daily. At the end of the year there were 70 producing oil wells in this field.

The second field discovered was the High Lonesome pool. The discovery well was the Nolen-Iles No. 1 in SE¼ SE¼ sec. 17, T. 16 S., R. 29 E., completed Nov. 20, 1939, at a total depth of 1824 ft., pumping 80 bbl. daily.

Chaves County.—A small producing well was drilled in sec. 29, T. 11 S., R. 25 E. It was drilled to a total depth of 1018 ft. with a reported initial production of 7 bbl. of oil and 3 bbl. of water on the pump. This new area is called the Grand Plains pool. Two other dry holes have been drilled near by and the results obtained are not very encouraging. Production was obtained from the San Andres limestone.

NORTHWESTERN NEW MEXICO

Drilling activity in the northwestern part of the state was confined chiefly to the Rattlesnake field, in San Juan County, with the completion of 13 producers and one dry hole. Three gas wells were drilled in the Kutz Canyon gas field. Several dry holes were drilled in the Farmington area.

ACKNOWLEDGMENTS

The author is indebted to Mr. John A. Frost, District Engineer, United States Geological Survey, Farmington, N. Mex., for information on the northwestern area. Mr. C. G. Staley, Proration Umpire for Lea and Eddy Counties, furnished the information on oil and gas production. Various operating companies and Mr. T. P. Wootton, of the State Bureau of Mines and Mineral Resources, Socorro, N. Mex., cooperated in furnishing general information and checking various data compiled by the Oil Conservation Commission.

Oil and Gas Developments in New York for 1939

By C. A. Hartnagel*

(New York Meeting, February 1940)

In 1939 the production of crude oil in New York totaled 5,105,000 bbl. This marks the third consecutive year production of crude oil has exceeded 5,000,000 bbl. and only once has this total been surpassed—in the year 1882, three years after the discovery of oil in Allegany County, when the annual production was more than 6,000,000 barrels.

The most gratifying feature of the industry was the increased demand for lubricants, which resulted in advanced prices for crude. From a price at the beginning of the year of $1.68 per barrel, six advances totaling 82¢ brought the year's closing to $2.50 per barrel. A further increase in price on Jan. 1, 1940, to $2.75 per barrel places the local industry in a strong position for the year's operations.

Most of the oil production of the state is now obtained by water-flooding, and the industry is practically stabilized. No new pools have been discovered in over 25 years, and border drilling indicates little prospect of extending the boundaries of the fields beyond their present limits. Deep drilling to the Oriskany sandstone in and close to the present oil fields has failed to find oil in substantial amounts.

Altogether, the oil pools of New York have produced during the 60 years that they have been exploited approximately 125,000,000 bbl. of oil. Following the flush production of 1882, the annual production gradually decreased and the year 1912 marked an all-time low of only 782,000 bbl. In 1919, as a result of flooding operations, a definite upward trend in oil production was recorded. During that year also the production of oil by water-flooding methods was approved by Legislative action. In the 21-yr. period beginning with 1919, oil production in the state has totaled 60,338,000 bbl. Thus it will be seen that by the aid of flooding methods nearly as much oil has been produced in the last 21 yr. as in the preceding 40 yr., although the latter period included the flush production in 1882.

As there is little hope of extending the area of the present producing oil fields of the state, producers and refiners are concerned regarding the future life of the fields. It is encouraging to observe that earlier esti-

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TABLE 1.—*Summary of Drilling Operations in the Gas Fields of Steuben and Allegany Counties*

Year	Steuben County								Allegany County								Summary of Developments in the Four Fields			
	Greenwood Field				Woodhull Field				State Line Field				Beech Hill Field							
	Total Wells Drilled	Pro-ductive	Dry	Initial Daily Production, M Cu. Ft.	Total Wells Drilled	Pro-ductive	Dry	Initial Daily Production, M Cu. Ft.	Total Wells Drilled	Pro-ductive	Dry	Initial Daily Production, M Cu. Ft.	Total Wells Drilled	Pro-ductive	Dry	Initial Daily Production, M Cu. Ft.	Total Wells Drilled	Pro-ductive	Dry	Initial Daily Production, M Cu. Ft.
1932	1	1		500													1	1		500
1933	1	1		13,500													1	1		13,500
1934	6	3	3	72,000					2	2		13,250					8	5	3	85,250
1935	2	1	1	15,000					13	9	4	219,800					15	10	5	234,800
1936									14	12	2	286,500					14	12	2	286,500
1937	2	1	1	15,000	19	19	0	314,018	3	3		54,400	1		1		25	23	2	383,418
1938	1		1		21	19	2	132,146	3	3		42,650	11	8	3	81,100	36	30	6	255,896
1939	4		4		10	8	2	19,178	2	1	1	17,000	6	3	3	32,000	22	12	10	68,178
	17	7	10		50	46	4		37	30	7		18	11	7		122	94	28	

TABLE 2.—*Oriskany Wells Completed in New York State in* 1939

	County and Township	Name of Well	Depth to Oriskany Sand, Ft.	Drilled by	Initial Daily Production, M Cu. Ft.	Pressure, Lb. per Sq. In.	Remarks
	Allegany:						
1	Alma	Vossler	5,294	G. L. Cabot			S. W.[3]
2	Amity	McEwen	4,398	Clancy et al.			S. W.
3	Andover	Padden Estate	4,627	Penn-York	12,000	2,000	S. W.
4	Angelica	Sydney Hooker	3,642	E. A. Williams			Dry
5	Independence	Ferris Rigby	5,509	Van Gelder			S. W.
6	Independence	C. G. Baham	5,370	Belmont Quad.			S. W.
7	Independence	O'Dell-Heselton	4,835	Belmont Quad.			S. W.
8	Willing	Dora Barber No. 2[1]	4,416	G. L. Cabot			S. W.
9	Willing	Thomas Maxwell No. 2[1]	4,828	Cunningham	17,000		
10	Willing	Floyd Wilson No. 2[2]	4,920	Empire Gas & Fuel Co.	9,000	1,450	
11	Willing	F. Hilligas No. 3[2]	4,882	Belmont Quad.	9,000	1,540	
12	Willing	C. Wilson No. 2[2]	4,927	Penn-York	14,000	1,275	
13	Willing	William Shear No. 2[2]	4,953	Cunningham			S. W.
14	Willing	Martin Sweeney[2]	4,958	Cunningham			S. W.
15	Willing	Kate Clark No. 1[2]	4,848	G. L. Cabot			S. W.
	Steuben:						
16	Addison	Fred Farnham	3,937	Van Gelder			S. W.
17	Cameron	F. Boyd	3,891	N. Y. S. Nat. Gas	13,900	1,880	
18	Cameron	Lloyd Hall	3,854	Hanley & Bird			S. W.
19	Cameron	William Preece	4,091	N. Y. S. Nat. Gas			S. W.
20	Cameron	Andrew Taft	4,193	Belmont Quad.			S. W.
21	Cameron	H. Thompson	4,084	N. Y. S. Nat. Gas			S. W.
22	Cameron	Sylvia Allen	4,177	New Penn, et al.			S. W.
23	Cameron	Lydia Owens	4,122	G. L. Cabot			S. W.
24	Cameron	Clifford Owens	4,253	G. L. Cabot			S. W.
25	Cameron	Federal Land Bank	4,170	G. L. Cabot			S. W.
26	Canisteo	Vanderhoof	3,744	Hanley & Bird			Dry
27	Greenwood	Ray Scribner	4,173	G. L. Cabot			S. W.
28	Greenwood	Larry Hyland	4,745	G. L. Cabot			S. W.
29	Greenwood	Lewis Weber	4,353	G. L. Cabot			Dry
30	Greenwood	William Ackley	4,721	Belmont Quad.			S. W.
31	Jasper	Albert Whiting	4,076	G. L. Cabot			S. W.
32	Jasper	E. Walrath	4,160	New Penn-Cunningham	4,200		
33	Jasper	A. H. Shaul	4,125	Belmont Quad.			Dry
34	Jasper	Bert Healy	4,180	Belmont Quad.			S. W.
35	Thurston	Foster Estate	3,931	Rehler et al.			Dry
36	Troupsburg	E. G. Cady	5,026	New Penn Dev. Co.	1,400		
37	Troupsburg	G. R. Cady	4,927	N. Y. S. Nat. Gas			Dry
38	Troupsburg	William Carpenter	4,208	N. Y. S. Nat. Gas			S. W.
39	Troupsburg	Lester Gurnsey	4,652	N. Y. S. Nat. Gas			S. W.
40	Tuscarora	John Hollis	3,608	N. Y. S. Nat. Gas	115		
41	Woodhull	George Hotaling No. 2	3,917	G. L. Cabot	1,621	625	
42	Woodhull	School Dist. No. 5	3,703	Clancy et al.	1,900		
43	Woodhull	George H. Rice No. 1	3,768	Hanley & Bird	2,500		
44	Woodhull	Della Calhoun	4,146	Sylvania	1,141		
45	Woodhull	William Meade No. 1	4,055	N. Y. S. Nat. Gas	1,400		
46	Woodhull	Parks Bros. No. 3	4,176	N. Y. S. Nat. Gas	7,400	1,025	
47	Woodhull	Neva Husted No. 2	4,001	G. L. Cabot	1,816	255	
48	Woodhull	C. Crane No. 3	3,931	G. L. Cabot			Dry
49	Woodhull	John Dorr	4,831	Williamsport Nat. Gas. Co.			Dry
50	Woodhull	M. E. Woodard No. 2	3,898	Hanley & Bird	1,400		
	Chemung:						
51	Baldwin	Clyde Bennett	3,424	N. Y. S. Nat. Gas			Dry
52	Erin	F. Husted	3,362	N. Y. S. Nat. Gas			S. W.
	Tompkins:						
53	Danby	M. Taubman	2,465	N. Y. S. Nat. Gas	4,985	920	
54	Danby	Miller Bros.	2,274	N. Y. S. Nat. Gas			Dry
55	Danby	Knuutila	2,607	N. Y. S. Nat. Gas			S. W.
56	Danby	R. Thomas	2,319	Belmont Quad.			Dry

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[1] State Line field.

[2] Beech Hill field.

[3] Salt water.

mates of production have had to be revised upward, both in the state and the nation. Few of the past estimates allow the New York fields a life of more than 10 yr. at the present rate of production. In fixing upon an estimate, however, many factors must be considered, for which data are not always readily available. Again, new methods may effect recoveries per acre that exceed expectation, such as the "five-spot" method of flooding and the more extended use of pressure pumps have achieved in the past. In Allegany and Steuben Counties, not over one-third of the oil area has been or is being flooded. No figures are available for Cattaraugus County. In Allegany County the average recovery by flooding methods is 3500 bbl. per acre, although 5000 bbl. and even greater yields are reported from some properties. Offsetting these facts it must be acknowledged that to date the better properties have been and are being flooded first and that later yields will be less.

From experience thus far gained, it would seem that future production by present methods from the New York fields could not be less than 70,000,000 bbl. If it were possible to weigh all factors entering into the problem, an estimate of 120,000,000 bbl. might not be excessive.

Natural Gas Developments

Unusual efforts to obtain additional gas production to augment the rapidly declining supplies from the Oriskany fields were made in New York during 1939. Fifty-six Oriskany wells were drilled but the combined initial capacity of the 18 producing wells was 104,778 M cu. ft. of gas, the new supplies falling far below those in each of the previous four years.

Since the discovery of the Oriskany gas fields in Allegany and Steuben Counties, the state's annual production has increased rapidly. From a production in the state of from six to eight billion cubic feet annually for a number of years previous to 1936, the production for that year in round numbers increased to 12 billion cu. ft., in 1937 to 21 billion cu. ft., and in 1938 to 39 billion cu. ft. The 1938 production marks an all-time high in the long history of the natural gas industry, which began at Fredonia, N. Y., in 1821.

There has been very little activity in other sections of the state. In the old Pulaski and Sandy Creek fields of Oswego County, where gas is obtained from the Trenton (Ordovician) limestone, three or four wells have been drilled. At Camden, Oneida County, only one producing well to the Trenton limestone was drilled during the year. The Trenton fields of Oswego and Oneida Counties are small and drilling operations are undertaken only when gas is needed for local use. No Trenton gas goes to distant markets.

In the Medina gas fields of western New York, activities have been limited to the drilling of a few wells. Much of the Medina territory can be supplied with gas from the Oriskany fields of New York and Pennsylvania, through existing pipe lines. During the flush period of Oriskany gas production and the low prices for gas, there has been little incentive for new drilling. In fact, many of the older Medina wells have been used for the storage of Oriskany gas.

ORISKANY PRODUCTION

Of the 56 wells drilled to the Oriskany in 1939 (Table 2), 22 were drilled in four fields, two of which, the State Line and the Beech Hill, are in Allegany County, and the two remaining, the Greenwood and the Woodhull, in Steuben County. Twelve producers out of the 22 wells had a combined initial daily capacity of 68,178 M cu. ft., which represents almost two-thirds the total initial production of 104,778 M cu. ft. daily of the Oriskany sandstone area. The remaining third was produced from six wildcat wells, one in Allegany County, four in Steuben County, and one in Tompkins County. At the end of the year, 11 wells were in process of drilling.

The State Line field, although principally in Willing township, extends over the town line into Alma township. Drilling in the State Line field was begun in 1934, finding two producers that year with a combined initial production of 13,250,000 cu. ft. of gas. In 1935, nine producers averaged 25 million cu. ft. each; the next year 12 producers averaged about 24 million cu. ft. each, and their combined production of 286,500,000 cu. ft. represents the peak initial daily capacity for the State Line field in any one year. In the last three years, only seven producers have been brought in, with an average production of 16 million cu. ft. daily. Of these, only one, the Thomas Maxwell No. 2, came in in 1939 (Table 2). Out of a total of 37 wells in this field, seven have been dry.

The most recent field, the Beech Hill, also in Willing township near its eastern boundary, is separated from the State Line field by only 2 or 3 miles. In all, 17 wells have been drilled in this field during 1938 and 1939 of which 11 had an average initial daily production of better than 10,000,000 cu. ft. each.

The Woodhull field was discovered in 1937, during which year 19 wells were drilled, all successful, their initial daily capacity totaling more than 314 million cu. ft. daily with initial flows from individual wells up to 28 million cu. ft. In 1938, two dry holes and 19 producing wells were drilled, with initial production totaling 132,146 M cu. ft. daily. During 1939, rock pressures were greatly reduced and most of the completed wells were shot in order to increase the flow. Recently pressure pumps have been installed in spite of the fact that the field is only three years old. The Woodhull field is a highly competitive area and heavy withdrawals of gas have caused its rapid depletion. In all, 50 wells have been put down in the field, only four of which were dry.

Oil and Gas Development in Ohio for 1939

By J. E. Schaefer*

(New York Meeting, February 1940)

Drilling activity in Ohio increased slightly in 1939. There were 1020 completions as compared to 910 in 1938. During the past six years the number of completions has varied little (Table 1).

Table 1.—*Well Completions in Ohio for Past Six Years*
Based on Figures from A.I.M.E. Transactions

Year	Number of Oil Wells	Number of Gas Wells	Number of Dry Holes	Total
1934	324	417	314	1,055
1935	[1]	[1]	369	1,022
1936	263	570	324	1,157
1937	317	503	451	1,271
1938	189	433	288	910
1939	170	501	349	1,020

[1] Number of oil and gas wells not divided in report for 1935; however, total was 653.

Oil production in Ohio has been gradually declining since 1896, when the peak production of 23,941,000 bbl. was reached (Fig. 1). Since that date production has slowly declined to an estimated production in 1939 of 3,144,134 bbl., the lowest in 53 years. This total production is divided approximately into the following grades of crude oil: Pennsylvania, 1,185,456 bbl.; Corning, 1,261,615 bbl.; Lima, 578,500 bbl.; Lodi, 104,740 bbl.; Cleveland, 13,823 bbl. Table 2 shows the prices paid for the various grades of crude oil.

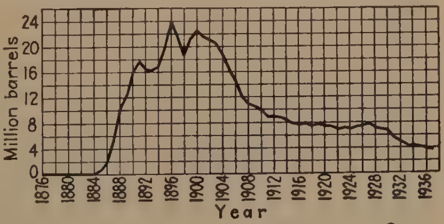

Fig. 1.—Petroleum production in Ohio. Based on figures of U. S. Bureau of Mines and *Oil and Gas Journal.*

This report is based upon figures available at the year's end from the offices of the various operating companies and from the various trade journals. Because of the short time available for the preparation of this report, the figures cannot all be considered final. Summarized at meeting; manuscript received at office of the Institute March 26, 1940.

* Geologist, The East Ohio Gas Co., Cleveland, Ohio.

As accurately as could be determined, at the close of the year approximately 25,680 wells were producing oil in Ohio, representing a decline of 1200 wells from the previous year. About 1370 producers were lost through abandonment, while 170 new producers were added during the year. The average annual production per well was 122.4 bbl., or a daily average of 0.335 bbl. per well.

TABLE 2.—*Prices for Crude Oil in Ohio during the Year* 1939
FROM *Oil and Gas Journal,* JANUARY 25, 1940

Date	Grade	Price per Bbl.	Date	Grade	Price per Bbl.
Jan. 1–Jan. 21....	Pennsylvania	$1.18	Jan. 1–Nov. 1.....	Corning	$0.97
Jan. 21–Feb. 1....	Pennsylvania	1.30	Nov. 1–Nov. 4.....	Corning	1.02
Feb. 1–Mar. 6.....	Pennsylvania	1.45	Nov. 4–Dec. 31....	Corning	1.12
Mar. 6–Oct. 6.....	Pennsylvania	1.55	Jan. 1–Dec. 31.....	Lima	0.90
Oct. 6–Nov. 1.....	Pennsylvania	1.80	Jan. 1–Dec. 31.....	Lodi	0.95
Nov. 1–Dec. 1....	Pennsylvania	1.94	Jan. 1–Dec. 31.....	Cleveland	1.00
Dec. 1–Dec. 31....	Pennsylvania	2.05			

Gas production in Ohio, like oil production, has been gradually declining for many years. Figures are not available at this time to make an estimate of the gas production in Ohio for 1939.

TABLE 3.—*Summary of Initial Volumes by Sands*
FROM FIGURES OF THE OHIO FUEL GAS COMPANY

Sand	Total Initial Volume		Average Initial Volume	
	Gas, M Cu. Ft.	Oil, Bbl.	Gas, M Cu. Ft.	Oil, Bbl.
Shallow........................	26,977	333	257	7
Berea........................	42,027	775	235	12
Shale........................	1,228	0	175	0
Oriskany........................	618	38	154	19
Newburg........................	45,098	77	1,367	26
Clinton........................	182,119	2,025	1,071	51
Trenton........................	497	86	166	7
	298,564	3,334	(av) 596	(av) 20

ACTIVITY BY FIELDS

Sub-Trenton.—During the past few years considerable interest has been shown in the so-called "green sand" of western Ohio, which is found from 500 to 700 ft. below the top of the Trenton. Ten tests were drilled to this horizon during the year, but all were dry. Table 4 shows the wells completed to this horizon during the year.

TABLE 4.—*Sub-Trenton Wells Completed in* 1939
FROM GEORGE D. LINDBERG, THE SUN OIL COMPANY

Farm and Number	Section	Township	County	Depth, Ft. Top Trenton	Depth, Ft. Top Green Horizon	Depth, Ft. Total
Wm. Morral No. 1	13	Marseilles	Wyandot	1,328	1,905	1,920
Thos. Ira No. 1		Franklin	Adams	1,467	2,089	2,162
H. E. Cross No. 1	13	Plain	Wood	1,115	1,793	2,185
S. Pogue No. 1		Spring Valley	Greene	1,059	1,512	1,575
R. B. Morrow No. 1	9	Jackson	Preble	1,136		1,630
Geo. Moore No. 1		Perry	Brown	843		1,443
L. Shinew No. 1	5	Portage	Wood	1,129	1,862	1,925
Lucy Damon No. 1	24	Harrison	Henry	1,741	2,378	2,513
Mary Crum No. 2	7	Clinton	Seneca	1,465	2,068	2,221
E. M. Marshall No. 1		Ceasars Creek	Greene	1,107	1,586	1,725

Trenton.—There were only 28 completions in the Trenton sand, compared with 75 in 1937 and 34 in 1938. Of the total, 3 were gas wells, 13 were oil wells and 12 were dry holes. It is estimated that approximately 8750 wells were producing oil from the Trenton sand in 1939. There were about 1000 abandonments during the year. Based on the estimated total production in Lima grade oil, the average annual production of Trenton wells is only about 66 bbl. per year.

TABLE 5.—*Wells Completed in Ohio in* 1939 *by Sands*
FROM FIGURES OF THE OHIO FUEL GAS COMPANY

Sand	Gas Wells Number	Gas Wells Per Cent	Oil Wells Number	Oil Wells Per Cent	Dry Holes Number	Dry Holes Per Cent	Total
Shallow	105	44	48	20	86	36	239
Berea	179	49	64	18	120	33	363
Gordon	0	0	0	0	3	100	3
Shale	7	100	0	0	0	0	7
Oriskany	4	36	2	18	5	46	11
Newburg	33	82	3	8	4	10	40
Clinton	170	53	40	13	109	34	319
Trenton	3	11	13	46	12	43	28
Sub-Trenton	0	0	0	0	10	100	10
	501	49	170	17	349	34	1,020

Clinton.—The Clinton sand continues to be the most important source of oil and gas in Ohio. There were 319 completions in this sand during the year, of which 170 were gas wells, 40 were oil wells and 109 were dry.

The average initial production of the gas wells was 1071 M cu. ft. and for the oil wells 51 bbl. Most of the wells represent extensions in the Clinton sand, which extends in an irregular manner from Lake Erie southward to the Ohio River.

One area of particular interest was developed during 1939—in the contiguous corners of Mary Ann, Newton, Newark and Madison townships, Licking County. The discovery well was drilled on the Steinmier farm, in the northeast corner of Newark township, on Dec. 1, 1938, with an open flow of one-half million cubic feet. Important interest in the field dates to the completion of a well on the Van Wey farm on the south edge of Mary Ann township in February 1939, which had an open flow of 6½ million cu. ft. and an initial rock pressure of 725 lb. For the remainder of 1939 there were 48 gas wells, 1 oil well and 11 dry holes drilled in the Clinton sand in this locality. During the course of drilling, 6 gas wells were completed in the Newburg sand. The Clinton sand is found at about 2500 ft. and the Newburg sand at approximately 2200 feet.

TABLE 6.—*Wells Completed in* 1939, *by Counties*

FROM FIGURES OF THE OHIO FUEL GAS COMPANY

County	Gas Wells	Oil Wells	Dry Holes	Total	County	Gas Wells	Oil Wells	Dry Holes	Total
Adams	0	0	1	1	Lawrence	8	0	3	11
Allen	0	1	1	2	Licking	67	24	34	125
Ashland	7	7	5	19	Logan	1	0	0	1
Athens	57	22	26	105	Lorain	8	3	6	17
Auglaize	0	0	3	3	Mahoning	0	0	2	2
Belmont	2	0	3	5	Medina	17	25	20	62
Brown	0	0	1	1	Meigs	25	0	14	39
Carroll	6	0	4	10	Monroe	22	5	9	36
Columbiana	1	0	8	9	Morgan	5	4	11	20
Coshocton	2	10	2	14	Muskingum	14	8	12	34
Cuyahoga	26	0	5	31	Noble	52	3	19	74
Fairfield	11	2	6	19	Perry	13	6	17	36
Gallia	3	0	1	4	Preble	0	0	1	1
Geauga	0	0	2	2	Putnam	1	4	1	6
Greene	0	0	1	1	Richland	1	0	3	4
Guernsey	25	3	19	47	Seneca	0	3	4	7
Hancock	0	0	2	2	Stark	24	0	5	29
Harrison	0	0	3	3	Summit	6	0	2	8
Henry	0	3	1	4	Tuscarawas	5	0	5	10
Hocking	3	5	5	13	Vinton	1	0	1	2
Holmes	11	1	10	22	Washington	41	20	35	96
Huron	0	0	1	1	Wayne	2	2	2	6
Jackson	3	0	1	4	Wood	1	0	2	3
Jefferson	6	2	3	11	Wyandot	0	2	3	5
Knox	24	5	23	52					
Lake	0	0	1	1		501	170	349	1,020

Berea.—The only important development in the shallow sands of eastern Ohio has been the "Yoker Valley district" in Wayne and Beaver townships, Noble County. The discovery well was completed in the latter part of 1938. During the year, 34 gas wells and 4 dry holes were completed. The Berea sand is found at depths ranging from 1500 to 1700 ft. and the initial rock pressures have averaged about 600 lb. Initial open flows here have been as high as 3½ million cu. ft., but the average has been less than 1 million cubic feet.

Secondary Recovery

During 1939, a bill was passed by the State Legislature legalizing the water-flooding of oil sands. Two water-flooding projects are now under way in the Berea sand of Chatham township, Medina County, which is generally known as the "Lodi." The Berea sand is found here at a relatively shallow depth of about 350 feet.

Horizontal Drilling

Leo Ranney, of McConnelsville, Ohio, in 1939 drilled "the world's first horizontal oil well," to quote his report, on the Dion S. Birney farm, Malta township, Morgan County, Ohio. The following information was supplied by Mr. Ranney.

The horizontal well was drilled among abandoned vertical wells, passing within 10 ft. of one, which had been shot with nitroglycerin. The horizontal core shows that the sand at that point had not been broken up or cracked by the vertical shot. The first horizontal well had a diameter of 2⅝ in. and originally was 802 ft. long. Later it was branched at 630 ft.; carried downward 6 ft. into better pay, then leveled off and drilled to a length of 953 ft. It was shot by Du Pont engineers with 1150 lb. of 80 per cent high-velocity gelatin and a line of T.N.T. Six weeks after the shot, the well was producing 7 bbl. of oil a day under a low vacuum applied each afternoon, oil and water flowing from the well by gravity.

Mr. Ranney also experimented with horizontal drilling from a shaft and with the application of hot gas to the sand through the well mouth.

He considered all the experiments successful, but says that more experimenting must be done, especially with repressuring in horizontal holes, before the method can be said to be generally effective.

Acknowledgments

The writer wishes to acknowledge the assistance of Mr. Kenneth Cottingham and Mr. L. W. Frost, of The Ohio Fuel Gas Co., and of Mr. D. T. Ring, of The Preston Oil Co., in the preparation of this report.

Oil and Gas Development in Oklahoma in 1939

By Thomas Brownfield*

(New York Meeting, February 1940)

The chronicle of the oil industry in Oklahoma in 1939 is one of declining production bolstered by strenuous efforts to find new pools or new producing horizons in the older, highly exploited, relatively shallow areas. Production, which averaged 608,000 bbl. daily in 1937, the post-depression peak, declined to 463,000 bbl. daily in 1938 and continued downward to 421,000 bbl. daily for the year 1939. While the state could produce somewhat more oil if demand warranted it, production in most areas is at as great a rate as could be justified on the basis of maximum efficient operation.

Outlet for Oklahoma crude has been seriously affected by the increase in production in the Illinois Basin. Crude movements from the Kansas-Oklahoma area to the northeastern consuming centers averaged 314,000 bbl. daily in 1939 as compared with 397,000 bbl. in 1938. Oklahoma producers bore the brunt of this loss of market.

The general production decline was accentuated by the August shutdown of 15 days, precipitated by the action of a major crude purchaser posting a 20-cent reduction in the price of crude. The Oklahoma Corporation Commission, in collaboration with other members of the Interstate Oil Compact Commission, ordered a complete shutdown of all producing wells in order to prevent the premature abandonment of stripper wells, which might result from a prolonged period of production at prices below operating costs. The reduction in price was forestalled, most major purchasers failing to meet the cut in view of the shutdown, and the company initiating the move rescinded its action.

Fear of the shutting in of oil wells, especially those making considerable quantities of water, is generally unfounded in the light of a superficial examination of the records. Oklahoma's unprorated pools, which produced 154,000 bbl. daily in May, declined to 152,000 bbl. in June and 143,000 bbl. in July. Immediately following the shutdown, the same pools produced 150,000 bbl. in September, 145,000 in October, and 145,000 in November. Thus, while the half month's production loss in August has not been made up, the wells apparently have produced at a greater rate since the shutdown than immediately preceding it.

Summarized at meeting; manuscript received at the office of the Institute March 20, 1940.

* Carter Oil Co., Tulsa, Oklahoma.

TABLE 1.—*Oil* and *Gas Production in Oklahoma*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
								During 1939		End of 1939	Number of Wells	
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Producing Oil[c]	Flowing	Artificial Lift
	CENTRAL OKLAHOMA											
1	Chandler, *Lincoln*	1924	1,160		11,339,200	370,840				51		51
2	Davenport, *Lincoln*	1924	2,090		11,641,364	169,725				124		124
3	Gessman, *Lincoln*	1934	110		339,701	24,090				10		10
4	Hoyt, *Lincoln*	1935	140		1,170,575	140,160	14			13		13
5	Laffoon, *Lincoln*	1932	100		1,426,442	217,540	10	2	1	9		9
6	Lincreek, *Lincoln*	1932	160		197,978	23,360		31		10		10
7	Sac & Fox, *Lincoln*	1924	*y*		1,975,743	1,109,235				135	*y*	*y*
8	Sporn, *Lincoln*	1936	100		503,602	106,580	10			10		10
9	Stroud, *Lincoln*	1923	580		8,626,684	127,385	69			29		29
10	Wilzetta & South Wilzetta, *Lincoln*	1934	240		892,521	178,485	13	4		13		13
11	Cleveland, *Pawnee*	1904	*y*		39,834,965	175,565	*y*			265		265
12	Jennings, *Pawnee*	1916	*y*		3,795,307	106,945	*y*	1		81		81
13	Keystone, *Pawnee*	1919	*y*		2,206,937	205,860	*y*	7		230		230
14	Lauderdale, *Pawnee*	1915	*y*		12,838,658	321,200	*y*			204		204
15	Maramec, *Pawnee*	1920	*y*		2,629,042	158,410	*y*			92		92
16	Terlton & North Terlton, *Pawnee*	1912 1917	*y*		3,864,336	77,380	*y*			92		92
17	Watchorn, *Pawnee*	1922	320		7,247,786	108,040	*y*	1		15		15
18	Coyle, *Payne*	1938	480		409,595	389,455	24	23		24	*y*	*y*
19	Garr, *Payne*	1920	*y*		2,196,730	131,400	*y*			33		33
20	Ingalls, *Payne*	1914	*y*		5,852,057	133,955	*y*			35		35
21	Ramsey, *Payne*	1938	370		2,019,524	1,479,710	37	20		37	*y*	*y*
22	Ripley, North, *Payne*	1923	90		325,775	30,295	*y*			3		3
23	Stillwater, *Payne*	1935	120		494,595	28,835	6			3		3
24	Yale-Quay, *Payne*	1914	*y*		21,017,441	522,680	*y*			173		173
25	Remainder Central Oklahoma				11,315,847	696,785				212		
26	Total Central Oklahoma				154,162,405	7,033,915				1,903		
	EAST CENTRAL OKLAHOMA											
27	Muskogee, *Muskogee*	1904	*y*		12,369,850	47,085	*y*			155		155
28	Deaner, *Okfuskee*	1920	*y*		2,989,845	124,100	*y*			97		97
29	Gypsy Hill, *Okfuskee*	1910	*y*		2,179,397	21,535	*y*			20		20
30	Josey, *Okfuskee*	1923	300	10	5,078,572	69,715	*y*			26		26
31	Weleetka, *Okfuskee*	1913	*y*		5,541,522	98,915	*y*	5		70		70
32	Bald Hill, *Okmulgee*	1908	*y*		48,456,841	424,860	*y*			818		818
33	Beggs, North & South, *Okmulgee*	1909 1911	*y*		11,750,754	112,055	*y*			109		109
34	Coalton, *Okmulgee*	1907	*y*		4,553,930	32,485	*y*			114		114
35	Hamilton Switch, *Okmulgee*	1909	*y*		3,053,407	38,690	*y*			84		84
36	Morris, *Okmulgee*	1907	*y*		24,642,074	159,140	*y*			275		275
37	Okmulgee, *Okmulgee*	1906	*y*		10,117,769	57,305	*y*			156		156
38	Pollyanna, *Okmulgee*	1921	*y*		2,235,215	154,760	*y*			234		234
39	Bird Creek, *Tulsa*	1906	*y*		69,331,009	447,125	*y*			1,847		1,847
40	Broken Arrow, *Tulsa*	1901	*y*		8,992,396	40,515	*y*			101		101
41	Jenks, *Tulsa*	1901	*y*		26,339,593	93,440	*y*	3		352		352
42	Red Fork, *Tulsa*	1901	*y*		7,647,214	29,565	*y*			90		90
43	Turley, *Tulsa*	1914	*y*		5,539,897	152,205	*y*			498		498
44	Wicey, *Tulsa*	1915	*y*		2,403,399	59,495	*y*			129		129
45	Coweta, *Wagoner*	1914	*y*		1,385,641	21,170	*y*	1		46		46
46	Oneta, *Wagoner*	1916	*y*		1,392,991	42,340	*y*			59		59
47	Stone Bluff, *Wagoner*	1915	*y*		3,700,531	108,040	*y*			178		178

[b] Footnotes to column heads and explanation of symbols are given on page 239.

TABLE 1.—*(Continued)*

	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
Line Number	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1		38	Various	Pen, Mis	S	Por	3,250	5,020		A		
2		43	Prue, Skinner	Pen	S	Por	2,600	3,580	50	ML		
3		44	Cleveland	Pen	S	Por	*y*	*y*		M		
4		40	1st Wilcox	Ord	S	Por	*y*	5,100	*y*			
5	*e*1,872*	21	Wilcox	Ord	S	Por	4,190	4,275		A	Wilcox	
6		46	Wilcox	Ord	S	Por	*y*	*y*				
7		46	Prue	Pen	S							
8		46	Simpson	Ord	S		4,500	4,600	*y*			
9		41	Various	Pen, Ord		*y*	4,240	4,290	50	A	Wilcox	4,520
10	*e*1,977	40	Hunton-Viola	Sil, Ord	L	*y*	4,230	4,536	*y*			
11		36	Cleveland-Bartlesville	Pen	S	Por	1,300	2,400				
12		38	Various	Pen	S	*y*	*y*	*y*				
13		38	Various	Pen Mis	SL		1,100	1,970				
14		37	Various	Pen, Ord	SL		1,185	3,000				
15		38	Various	Pen, Mis	SL		2,400	3,200				
16		38	Various	Pen, Ord	S		1,460	3,105				
17		41	Wilcox-Layton	Pen, Ord	S	Por			*y*	*y*		
18		46	Wilcox	Ord	S	*y*	*y*	*y*	*y*			
19		38	Various	Pen, Mis, Ord	SL							
20		40	Various	Pen, Ord	SL		3,115	3,760				
21		43	Wilcox	Ord	S		4,768	4,795	27			
22		43	Wilcox	Ord	S	Por	*y*	*y*	*y*	*y*		
23	*e*1,700	40	Wilcox	Ord	S	Por	4,300	4,306	6	A	Wilcox	4,306
24		38	Various	Pen, Ord	LS		2,670	3,580				
25												
26		39.5										
27		38	Various				1,052	1,790		F		
28		38	Deaner-Lyons-Wilcox	Mis, Ord	S		2,800	3,650				
29		33	Various	Pen, Ord	S		2,430	3,290				
30		40	Wilcox	Ord	S		3,600	3,650	50	D	Wilcox	3,700
31		39	Glenn-Gilcrease-Lyons	Pen	S		2,530	2,660	30			
32		30	Various	Pen	S		750	2,250				
33		37	Various	Pen, Mis, Ord	SL		1,760	2,550				
34		30	Various	Pen, Ord	S		1,300	2,835				
35		29	Glenn-Wilcox	Pen, Ord	S		1,385	2,700				
36		36	Various	Pen, Mis, Ord	SL		1,600	2,450				
37		30	Various	Pen, Ord	S		1,240	2,750				
38		34	Various	Pen	S		1,365	2,285				
39		31	Bartlesville-Burgess	Pen, Mis	S		1,110	1,345				
40		37	Bartlesville-Dutcher	Pen	S		1,350	1,500				
41		36	Various	Pen, Mis	SL		1,400	1,800				
42		34	Various	Pen, Cam-Ord	LS		599	2,160				
43		32	Bartlesville-Siliceous	Pen, Cam-Ord	SL		1,260	1,945				
44		37	Various	Pen	S		1,480	1,950				
45		38	Dutcher-Burgen	Pen, Ord	S		700	1,280				
46		38	Dutcher	Pen	S		1,000	1,200				
47		36	Wilcox-Turkey Mt.	Ord, Cam	S		1,840	2,275				

* *e* means "bottom-hole pressure."

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
								During 1939		End of 1939	Number of Wells	
			Oil	Gas^b	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Producing Oil^c	Flowing	Artificial Lift
48	Remainder E. Cent. Oklahoma				39,295,247	1,358,165				1,638		
49	Total East Cent. Oklahoma				298,997,094	3,692,705				7,096		
	EAST CENTRAL-CREEK COUNTY											
50	Arno	1923	*y*		2,514,629	64,605	*y*			17		17
51	Big Pond	1924	*y*		4,283,446	132,495	*y*			36		36
52	Bowden	1906	*y*		20,633,309	127,385	*y*			244		244
53	Bristow	1916	*y*		36,819,510	376,315	*y*			154		154
54	Bristow, North	1922	*y*		3,054,406	104,755	*y*			100		100
55	Bristow, West	1922	*y*		1,250,305	51,830	*y*			21		21
56	Cushing	1912	24,500		352,774,097	3,451,805	3,665			1,874		1,874
57	Deep Fork	1920	*y*		5,318,224	146,730	*y*			163		163
58	Depew	1915	*y*		35,712,750	329,595	*y*			80		80
59	Glenn Pool	1905	14,720		218,029,735	1,195,010	*y*	2		1,794		1,794
60	Independent	1908	*y*		3,758,207	187,975	*y*			44		44
61	Iron Post	1917	*y*		2,243,630	33,215	*y*			60		60
62	Manford (Deep and Shallow)	1922	*y*		5,269,492	427,415	*y*	2		270		270
63	Mounds	1915	*y*		2,910,114	90,885	*y*			53		53
64	Olive	1914	*y*		4,506,647	270,100	*y*			207		207
65	Sapulpa	1909	*y*		6,070,590	75,190	*y*	9		103		103
66	Sapulpa, South	1910	*y*		5,888,482	65,335	*y*			73		73
67	Slick	1913	*y*		32,600,436	347,115	*y*			179		179
68	Wilcox	1919	*y*		3,473,697	192,720	*y*			64		64
69	Remainder E. Central Creek County				10,635,738	992,435	*y*			525		
70	Total E. Central Creek County				757,747,444	8,662,910				6,061		
	NORTHERN OKLAHOMA											
71	Garber, *Garfield*	1916	4,605		53,887,157	645,685	971	7		577		577
72	Hillsdale, *Garfield*	1938	20		69,350	43,435		1		2		2
73	Waukomis, *Garfield*	1938	10		29,203	10,585	1			1		1
74	Caldwell, *Grant*	1929	30		252,330	8,760				2		2
75	Deer Creek, *Grant*	1922	*y*		1,154,697	71,175				11		11
76	Lamont, *Grant*	1937	40		342,595	129,210	2			2	1	1
77	Blackwell, *Kay*	1918	*y*		4,393,792	155,125				43		43
78	Braman & North Braman, *Kay*	1924	1,180		22,062,653	471,215		1		95		95
79	Braman, Southeast, *Kay*	1938	*y*		87,283	61,685		2		4		4
80	Dilworth, *Kay*	1917	5,280	2,720	4,968,628	157,680				85		85
81	Hubbard, *Kay*	1924	620		8,041,258	190,165				38		38
82	Ponca City, *Kay*	1917	1,680		6,217,430	77,015		1		37		37
83	Thomas, *Kay*	1924	*y*		7,019,707	80,665				17		17
84	Tonkawa, *Kay*	1921	3,050		120,109,427	677,075	929			313		313
85	Vernon, *Kay*	1925	920		3,146,172	97,455				18		18
86	Crescent, *Logan*	1933	1,010		12,114,338	979,660	52			47		47
87	Hull, *Logan*	1934	80		203.491	15,695				2		2
88	Langston, *Logan*	1934	300		857,267	125,925		1		13		13
89	Lovell, *Logan*	1928	*y*		2,580,152	33,580				9		9
90	Lovell, West, *Logan*	1936	20		95,176	4,380	2			1		1
91	Marshall, *Logan*	1927	*y*		11,654,193	75,555				24		24
92	Meridian, *Logan*	1938	70		95,147	72,635	7	5		7		7
93	Billings-Wilcox, *Noble*	1936	730		6,804,839	2,171,385	72	3		72	*y*	*y*
94	Billings (Shallow), *Noble*	1917	600	60	6,173,586	11,315				7		7
95	Lucien, *Noble*	1932	3,820		23,650,163	3,014,535	126	2		124	*y*	*y*
96	Lucien, North—*Noble*	1936	*y*		592,638	251,485		2		10	*y*	*y*
97	Marathon, *Noble*	1935	*y*	30	128,168	8,760		1		3		3
98	Otoe City, *Noble*	1930	10		51,903	4,015				1		1

TABLE 1.—(*Continued*)

	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Agv. Ft.					
Line Number	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
48												
49		34.9										
50		36										
51		32	Various	Pen, Ord	S							
52		32										
53		35	Various	Pen, Mis, Ord	SL		2,700	3,200				
54		35	Various	Pen, Mis, Ord	SL							
55		35			S		3,152	3,155				
56		38	Numerous Horizons	Pen, Ord	SL	Por			*x*	AF		
57		42										
58		32	Gleen-Dutcher Wilcox	Pen, Ord	S		2,700	3,397				
59	750	34	Glenn-Wilcox	Pen, Ord	S	Por	*y*	*y*	*y*	ML	Arbuckle	2,964
60		35	Dutcher-Wilcox	Pen, Ord	S		2,100	2,550				
61		36	Wheeler-Prue	Pen	S		2,420	2,475				
62		39	Various	Pen, Mis, Ord	SL		1,550	2,980				
63		33	Various	Pen, Ord	S		1,100	2,400				
64		36	Various	Pen, Ord	S		1,300	3,480				
65		34	Various				1,000	2,290				
66		36										
67		32	Various	Pen, Mis			2,340	3,088			Wilcox	3,140
68		35	Wilcox	Ord	S		2,672	2,687	15			
69												
70		35.98										
71		43	Various	Per, Pen	SL	Por	1,100	4,200	*y*	AF	*y*	*y*
72		44	*y*			*y*	*y*	*y*	*y*		*y*	
73		53	Marshall		S	*y*	7,260	7,280	20		*y*	*y*
74		44	Wilcox	Ord	S	Por	*y*	*y*	6	A	*y*	*y*
75		39	Various	Pen, Ord	S		2,900	4,175	*y*			
76		49	Wilcox	Ord	S	*y*	5,400	5,410	10		*y*	*y*
77		40	Various	Pen, Cam-Ord	SL		1,600	3,400				
78		41	Various	Pen, Ord	SL	Por	*y*	*y*	*y*	A		
79		43	*y*	*y*	*y*	*y*	*y*	*y*	*y*		*y*	*y*
80		40	Various	Pen, Ord, Per	S, SL	Por			*y*	A		
81		39	Various	Pen, Ord	SL	Por	*y*	*y*	*y*	AF	*y*	*y*
82		38	Various	Pen, Per	SL		1,500	3,900		A		
83		41	Various	Pen, Mis, Ord	SL	Por			*y*	*x*		
84		42	Various	Pen, Ord	S	Por	2,660	4,075	*y*	*x*		
85		40	Stalnaker	Mis	S				*y*	*x*		
86		42	Layton 2d Wilcox	Pen, Ord	S	23				AF		
87		40	Layton	Pen	S	Por		4,800				
88		45	Wilcox	Ord	S	Por	5,100	5,145		A	Wilcox	5,194
89		40	Tonkawa-Wilcox	Pen, Ord	S	*y*	*y*	*y*				
90		54	Wilcox	Ord	S	Por	*y*		*y*	*y*		
91	1,950	40	Tonkawa	Pen	S	*y*	*y*	*y*	*y*			
92		48	Wilcox	Ord	S	*y*	5,200	5,220	20			
93	*e*1,720	41	Wilcox	Ord	S	Por	4,250	*y*	*y*	A		
94		41	Hoover	Pen	S	Por			50	A		
95		42	Simpson-Wilcox Viola	Ord	SL	Por	*y*	5,200	*y*	*y*		
96	*e*2,200	44	Wilcox	Ord	S	Por	*y*	*y*	*y*	*y*		
97	1,665	42	Wilcox	Ord	S	Por	*y*	*y*	34	A		
98		39	Layton	Pen	S	Por	3,284	3,314	30	*y*		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939	Number of Wells	
								Completed	Abandoned	Producing Oil[c]	Flowing	Artificial Lift
99	Polo, *Noble*	1934	370		3,384,037	424,495	37	1		33		33
100	Sams, *Noble*	1925	*y*		2,232,042	41,610				8		8
101	Remainder Northern Oklahoma				3,285,422	143,810				40		
102	Total Northern Oklahoma				305,684,244	10,255,770				1,646		
	OKLAHOMA CITY AREA											
103	Moore, *Cleveland*	1936	700		7,376,654	1,012,145	40			39	*y*	*y*
104	Noble, *Cleveland*	1938	10		28,672	7,665	1		1	[1]		
105	Norman, *Cleveland*	1939	20		5,475	5,475				2	*y*	*y*
106	Britton,[2] *Oklahoma*	1935	360		2,070,141	235,060		1		29	*y*	*y*
107	Britton, South,[3] *Oklahoma*	1938	10		68,488	40,880	1			1		
108	Edmond, *Oklahoma*	1930	1,030	20	15,325,812	1,677,175	102	1		95		95
109	Jones, *Oklahoma*	1939	*y*		2,920	2,920		1		1		
110	Newalla, South, *Oklahoma*	1939	*y*		13,870	13,870		1		1		
111	Nicoma Park, *Oklahoma*	1929	30		328,216	11,315	2			2		2
	Oklahoma City, *Oklahoma:*											
112	Wilcox	1929			346,712,186	29,680,694					*y*	*y*
113	Lower Simpson	1928			106,511,311	4,115,702					*y*	*y*
114	Upper Simpson	1932			2,094,510	231,212					*y*	*y*
115	Cleveland				1,543,045						*y*	*y*
116	Pawhuska	1928			1,676,903	698,500					*y*	*y*
117	Other Zones	1928			20,222,038	945,587					*y*	*y*
118	Total		14,100		478,759,993	35,671,695	1,474	15		1,020		
119	Total Oklahoma City Area				503,980,241	38,678,200				1,190		
	OSAGE COUNTY											
120	Atlantic	1924	*y*		*x*	330,325				96		96
121	Avant	1904	*y*		*x*	640,575				768		768
122	Avant, West	1905	*y*		*x*	60,590				185		185
123	Barnsdall	1916	*y*		*x*	74,825		2		215		215
124	Bartlesville	1904	*y*		*x*	19,710				81		81
125	Boston	1904	*y*		*x*	132,130				46		46
126	Burbank, *Osage and Kay*	1920	22,210	230	199,026,718	2,733,485	2,204			1,748		1,748
127	Burbank, South { Original Discovery Extension	1926 1934	4,270		25,099,520	3,163,455	287			241	*y*	*y*
128	Dewey	1904	*y*		*x*	22,995		8		108		108
129	Domes	1917	*y*		*x*	86,870				218		218
130	Fairfax	1925	*y*		483,070	52,925				16		16
131	Flat Rock	1906	*y*		*x*	292,365				600		600
132	Hominy	1916	300		*x*	27,740				11		11
133	Hominy, East	1918	450		*x*	28,105				24		24
134	Naval Reserve	1933	2,720	160	14,636,017	1,431,165	254			242		242
135	Osage City	1904	*y*		*x*	275,575				234		234
136	Osage-Hominy	1917	*y*		*x*	232,870				139		139
137	Pershing	1918	*y*		*x*	104,025				343		343
138	Petit	1923	380		*x*	33,945				20		20
139	Quapaw	1914	*y*		*x*	44,895				239		239

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[1] Abandoned.
[2] Formerly reported as "North Britton" and "South Britton."
[3] Formerly reported as "Olsen, Van Neck."

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Agv. Ft. Top Prod. Zone	Depth, Agv. Ft. Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
99		41	Various	Pen, Mis, Ord	S	y	4,823	4,900	y	y		
100		42		Pen	S		1,902	1,912	10			
101												
102		41.96										
103		41	2d Wilcox	Ord	S	Por				A		
104		39	2d Wilcox	Ord	S		7,670	7,672	2			
105		38	y	y	y	y	y	y	y			
106	2,000	45	Simpson	Ord	DL	Por				AF		
107		35	2d Wilcox		S		6,738	6,766	28			
108		39	Simpson, Wilcox	Ord		Por				AF	Arbuckle	7,000
109		35	Cleveland	Pen	S	y	4,796	4,808	12		2d Wilcox	5,998
110		38	Hunton	Sil-Dev	L		6,004	6,095	91		2d Wilcox	6,610
111		36	Trosper	Pen	S	Por	6,157	6,168	11	ML		
112	e2,600	38	Wilcox	Ord	S	22.5			y	y		
113	e2,660	36	Lower Simpson	Ord	S	Por			y	y		
114	1,000		Misener	Pen	S	Por			y	y		
115		35	Cleveland	Pen	S				y	y		
116			Pawhuska	Pen	L	Por			y	y		
117			Arbuckle	Cam, Ord	L	Cav			y	y		
118		37						6,700				
119		37.3										
120		39	Burgess, Siliceous	Mis, Cam-Ord	S L		2,500 2,750	2,525 2,765	25 15			
121	RP	33	Bartlesville, Burgess	Pen, Mis	S S		1,400 1,465	1,450 1,600				
122		32	Bartlesville, Burgess	Pen, Mis	S S							
123		33	Peru, Bartlesville	Pen	S		1,100 1,550	y 1,725	y 75			
124		33	Various	Pen	L, S		650	1,265				
125		37	Various	Pen, Cam-Ord	SL		1,500	2,620				
126	RP	38	Burbank	Pen	S		2,700	2,850	60	ML	Granite	4,240
127	PM	38	Burbank	Pen	S			2,850				
128		33	Various	Pen	LS		650	1,265				
129		36	Stray, Bartlesville, Mississippi	Pen, Mis	SL		1,057 1,680 1,880	1,124 1,780 1,925	67 100 45			
130		38	Burbank	Pen	S	20–25			y	ML		
131	RP	34	Bartlesville, Burgess	Pen	S		1,110 1,345	1,205 1,365	95 20		Wilcox	1.667
132		34	Burgen, Siliceous lime	Ord	SD		2,625	2,685	50	A	Arbuckle	3,206
133		34	Bartlesville	Pen	S		2,160	2,210		A	Arbuckle	2,857
134		39	Burbank	Pen	S				y	y		
135		37	Cleveland, Bartlesville	Pen	S		1,620 2,250	1,645 2,280	25 30		Mississippi	2,431
136		37	Various	Pen	SL		y	y	y			
137		35	Cleveland, Bartlesville	Pen	S		1,385 2,033	1,400 2,063	15 30	D		
138		36	Simpson dolomite	Ord	SD	Por	y	y	45	A	2d Wilcox	
139		34	Bartlesville	Pen	S		1,720	1,780	60			

TABLE 1.—(*Continued*)

Line Number	Field, County	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
								During 1939		End of 1939	Number of Wells	
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Producing Oil[c]	Flowing	Artificial Lift
140	Ramona	1911	*y*		*x*	71,905				81		81
141	Skiatook	1911	*y*		*x*	18,250				30		30
142	Tidal-Osage	1918	*y*		*x*	82,855				108		108
143	Wildhorse	1912	*y*		*x*	291,635				429		429
144	Wildhorse, North	1919	*y*		*x*	27,375				33		33
145	Woolaroc	1917	*y*		*x*	62,780				172		172
146	Wynona	1917	*y*		*x*	83,585				175		175
147	Remainder Osage County				*x*	1,552,345				1,969		
148	Total Osage County				558,747,140[4]	11,979,300[5]				8,571		
	SEMINOLE AREA											
149	Adams, *Hughes*	1936	200		788,566	266,815	10			10		10
150	Alabama, *Hughes*	1923	*y*		681,206	46,720				31		31
151	Buchner, *Hughes*	1924	*y*		599,823	11,315				2		2
152	Calvin, *Hughes*	1938	20		48,645	10,220	2			2		2
153	Fish, *Hughes*	1934	*y*		14,654,375	1,369,480	*y*	9		123	*y*	*y*
154	Fream, *Hughes*	1938	20		11,315	6,935		2		2		2
155	Fuhrman, *Hughes*	1925	*y*		920,791	14,600				13		13
156	Gilcrease, *Hughes*	1924	*y*		181,636	2,920				2		2
157	Holdenville, North, *Hughes*	1926	*y*		32,955	2,190				1		1
158	Holdenville, West, *Hughes*	1916	*y*		4,659,096	274,480				123		123
159	Papoose, *Hughes*	1923	2,660		22,928,634	237,615	279			58		58
160	Yeager, *Hughes*	1925	*y*		1,927,009	39,785				8		8
161	Yeager, North, *Hughes*	1936	*y*		78,724	33,945		2		8		8
162	Dill, *Okfuskee* (West half)	1931	840		2,248,213	360,985	37	8		32		32
163	Olympic,[6] *Okfuskee* (West half)	1934	3,440		10,054,577	1,029,665	348			336		336
164	Asher, *Pottawatomie*	1929	*y*		3,559,648	24,820				8		8
165	Asher, West, *Pottawatomie*	1930	675		7,275,050	101,105	69			34		34
166	Avoca, *Pottawatomie*	1938	80		223,747	193,085	8	6		8	*y*	*y*
167	Earlsboro, West, *Pottawatomie*	1927	*y*		1,942,082	103,660				21		21
168	Gray, *Pottawatomie*	1932	310		3,693,956	284,700	31			23		23
169	Grisso, *Pottawatomie*	1934	*y*		303,671	45,990		1		4		4
170	King, *Pottawatomie*	1930	*y*		76,590	32,120				2	*y*	*y*
171	King, West, *Pottawatomie*	1939	*y*		27,740	27,740		3		3	*y*	*y*
172	Maud, *Pottawatomie*	1928	1,540		11,658,571	273,385	155	1		60		60
173	Sacred Heart, *Pottawatomie*	1939	*y*		52,560	52,560		6		6	*y*	*y*
174	Shawnee, *Pottawatomie*	1934	*y*		1,641,887	400,405		12		35	*y*	*y*
175	Shawnee, East, *Pottawatomie*	1937	20		56,406	10,220	2		1	1		1
176	Shawnee, North, *Pottawatomie*	1937	10		55,393	13,505				1		1
177	St. Louis, *Pottawatomie*	1927	11,120		138,533,215	11,357,705	1,136	189		888	*y*	*y*
178	Tecumseh, *Pottawatomie*	1937	10		91,442	34,310	1			1		1
179	Allen (Deep), *Seminole*	1927	3,860		47,924,693	2,100,575	453	17		307		307
180	Bethel, *Seminole*	1925	570		1,700,656	61,320				38		38
181	Bethel, North, *Seminole*	1936	320		2,410,761	696,785	30			29		29
182	Bowlegs, *Seminole*	1926	3,600		114,317,449	2,710,125	364	1		232		232
183	Carr City, *Seminole*	1927	1,210		29,180,622	930,020	121	1		85		85
184	Cromwell, *Seminole*	1923	4,790	130	55,035,384	1,064,340	492			252		252
185	Cromwell, South, *Seminole*	1937	80		334,028	123,005	8			8		8
186	Dora, *Seminole*	1935	980		3,488,692	1,141,355		16		98		98
187	Earlsboro, *Seminole*	1926	4,750		122,620,409	1,553,075	496	1		181		181

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[4] Includes 32,710,309 bbl. produced in Burbank-Kay County.
[5] Includes 290,905 bbl. produced in Burbank-Kay County.
[6] Formerly reported as "Olympic" and "North Olympic."

TABLE 1.—(*Continued*)

	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
Line Number	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
140		33	Big Lime Bartlesville Burgess	Pen Mis	LS		934 1,687 1,753	1,034 1,707 1,773	100 20 20			
141		34	Bartlesville Burgess Mississippi	Pen Mis	SL		1,370 1,460 1,500	1,390 1,470 1,650	20 10 150			
142		36	Burgess, Bartlesville	Pen	S							
143		35	Various	Pen, Ord	S, L		3,550	4,260				
144		35	Various	Pen, Ord	SL							
145		34	Skinner, Bartlesville	Pen	S							
146		35	Various	Pen, Mis	SL		1,600	2,281				
147												
148		37.12										
149	1,500	40	Hunton-Misener	Sil-Mis	Lime	P			15	A	Wilcox	4,317
150		39	Deaner Lyons	Mis	S, L		2,910 3,130	3,310 3,260	400 130			
151		35	Booch-Cromwell	Pen, Mis	S		*y*	*y*	*y*			
152		36	Viola	Ord	L		*y*	*y*	*y*			
153		37	Various	Pen, Mis, Ord	S		*y*	*y*	*y*			
154		36	Cromwell	Mis	S		3,335	3,354	19			
155		37	Gilcrease-Cromwell	Pen, Mis	S		*y*	*y*	*y*			
156		39	Gilcrease	Pen	S		*y*	*y*	*y*			
158		40	(Sand)				3,418	3,437	19			
158		37	Various	Pen, Ord	S							
159		36	Cromwell	Pen	S	Por			10	A	Wilcox	
160		39	Various	Pen, Mis, Sil-Dev	SL							
161		37	Cromwell-Hunton	Mis, Sil-Dev								
162		40	Hunton-Cromwell	Sil-Pen	SL	Por			30			
163		34	Senora- Cromwell	Pen	S	Por	1,685 3,433	1,735 3,475	*y* *y*			
164		39	Wanette-Viola	Ord	SL		*y*	*y*	*y*			
165		43	Wanette				3,450					
166		39	Viola	Ord	L		4,206	4,208	2			
167		38	Hunton	Sil-Dev	L		*y*	*y*	*y*			
168	*e*1,440	40	Wilcox	Ord	S	Por	2,500	3,475	25	A	Wilcox	3,500
169		36	Hunton	Sil	L		4,030	4,050			Wilcox	4,860
170		41	Viola	Ord	L		4,374	4,416	42			
171		41	Hunton	Sil	L		4,281	4,306	25			
172	*e*1,000	38	Misener-Hunton	Mis, Sil	SL	Por	4,130	4,140	10	A	Wilcox	4,330
173		32	Earlsboro		S		2,862	2,883	21			
174	500	34	Earlsboro	Pen	S	Por			*y*	*y*		
175		31	Wilcox	Ord	*y*		4,839	4,844	5			
176		36	Simpson		S		4,853	4,886	33			
177	600	38	Hunton-Simpson	Sil, Ord	LS	Por	*y*	*y*	*y*	*y*		
178		37	Simpson dolomite	Ord			5,125	5,238	113			
179		36	Various	Mis, Sil, Ord	SL		2,500	4,250				
180		36	Booch	Pen	S	Silty			27*y*	ML		
181	1,300	40	Cromwell	Pen	S	Por	3,630	3,615	20	A	Cromwell	
182		40	Wilcox or Simpson	Ord	S	Por			30	A		
183		40	Hunton-Wilcox	Pen-Ord	LS	Por	4,180	4,205		A	Wilcox	4,210
184		37	Cromwell	Pen	S	Por		3,400		AF	Wilcox	4,226
185		37	Wilcox	Ord	S		4,176	4,189	13			
186		35	Boggy		S		2,947	2,959				
187		38	Earlsboro-Wilcox	Pen, Ord	S		*y*	*y*	*y*			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
								During 1939		End of 1939	Number of Wells	
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Producing Oil[c]	Flowing	Artificial Lift
188	Earlsboro, East, *Seminole*	1929	1,980		37,409,322	830,740	185			99		99
189	Earlsboro, North, *Seminole*	1936	*y*		2,649,327	1,070,910		1		34		34
190	Earlsboro, South, *Seminole*	1930	310		8,434,423	187,610	31			18		18
191	Grayson, *Seminole*	1935	*y*		1,207,692	462,455		2		36		36
192	Hazel, *Seminole*	1938	200		277,774	173,010	20	2		20	*y*	*y*
193	Jackson, *Seminole*	1925	*y*		673,704	28,470				15		15
194	Keokuk, *Seminole*	1933	2,320		9,460,541	1,177,490	107			103	*y*	*y*
195	Konawa, *Seminole*	1929	1,200		14,454,557	404,420	122	1		101		101
196	Konawa, East, *Seminole*	1936	*y*		186,045	20,075				6		6
197	Konawa, South, *Seminole*	1938	*y*		46,039	44,895				11		11
198	Konawa, West, *Seminole*	1938	110		310,890	205,495	11	1		11	*y*	*y*
199	Little River, *Seminole*	1927	4,935		107,060,902	2,366,660	588	4		251		251
200	Little River, East, *Seminole*	1928	650		16,242,389	255,865	*y*	1		64		64
201	Little River, West, *Seminole*	1938	*y*		408,086	347,115		3		10	*y*	*y*
202	Mission, *Seminole*	1928	1,240		24,564,329	489,100	122	1		70		70
203	Rosanna, *Seminole*	1924	*y*		1,390,095	112,055		6		21		21
204	Sancho, *Seminole*	1929	*y*		304,138	12,045				5		5
205	Sasakwa, *Seminole*	1927	940		10,186,345	468,295	101	3		62		62
206	Sasakwa Townsite, *Seminole*	1933	120		2,103,949	143,445				8		8
207	Searight, *Seminole*	1926	1,370		33,436,832	437,270	144	1		66		66
208	Searight, East, *Seminole*	1939	*y*		102,565	102,565				4	*y*	*y*
209	Searight, North, *Seminole*	1934	380		2,955,892	329,230	19	1		14		14
210	Seminole City, *Seminole*	1926	3,860		124,102,244	2,627,635	394	4		212		212
211	Seminole, East, *Seminole*	1926	1,280		7,477,043	446,030	129			96		96
212	Seminole, West, *Seminole*	1935	300		12,008,161	502,605	28			23		23
213	Swan, *Seminole*	1938	10		9,116	4,015	1			1		1
214	Transco, *Seminole*	1926	*y*		104,143	1,460				5		5
215	Traugh (Deep), *Seminole*	1937	190		608,391	277,400	15	1		15	*y*	*y*
216	Traugh (Shallow), *Seminole*	1937	270		656,901	117,895	27			26		26
217	Tyrola, *Seminole*	1937	50		54,292	41,610	5	3		5	*y*	*y*
218	Wetley, *Seminole*	1927	*y*		337,044	43,800				17		17
219	Wewoka, *Seminole*	1923	1,380		39,448,020	379,600	231			105		105
220	Wewoka, East, *Seminole*	1927	230		1,654,187	74,095	29			9		9
221	Wewoka Townsite, *Seminole*	1924	280		2,869,751	156,950	40			26		26
222	Wofford, *Seminole*	1935	*y*		603,021	65,335				5		5
223	Remainder Seminole Area				6,125,759	118,260				30		
224	Total Seminole Area				1,075,944,126	41,569,485				4,680		
	SOUTHEASTERN OKLAHOMA											
225	Brock, *Carter*	1922	600		3,962,637	85,045				127		127
226	Caddo, *Carter*	1939	*y*		10,585	10,585		1		1		
227	Centrahoma, *Coal*	1937	40		49,762	19,710	2			2		2
228	Clarita, *Coal*	1937	30	10	41,862	12,045	4			3		3
229	Citra, *Hughes*	1937	40		5,668		1			1		1
230	Byars, *McClain*	1939	*y*		2,190	2,190		1		1		
231	Enos, *Marshall*	1933	*y*		123,745	10,585				25		25
232	Isom Springs, *Marshall*	1931	*y*		127,277	22,265		1		44		44
233	Kingston, *Marshall*	1932	*y*		16,407					9		9
234	Madill, *Marshall*	1925	*y*		1,080,926	17,885				81		81
235	Ada, East, *Pontotoc*	1928	*y*		211,502	27,375		1		17		17

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
188		39	Calvin-Hunton, Wilcox	Pen, Sil, Ord	S, L		y	4,250	y			
189	e1,940	41	{ Hunton	Sil	L	y	y	y	y	A	Wilcox	4,680
	e1,365		{ Wilcox	Ord	S	Por	4,640	4,650	10	A	Wilcox	4,680
190		39	Wilcox	Ord	S	Por	4,200	4,225	25	A	Wilcox	4,225
191		40	Hunton-Simpson, Dolomite	Sil, Ord	SL	y	4,030	4,050	20	y	y	y
192		36	Thurmon-Boggy		S		2,991	3,003	12	y		
193		38	Booch		S		y	y	y			
194		40	{ Misener-Hunton	Mis	SL	y	4,117	4,152	15–20	A	Wilcox	4,483
			{ Hunton	Sil	L	y			y	y	Wilcox	4,483
195		36	Earlsboro-Cromwell-Simpson	Pen, Mis, Ord	S		y	y				
196		39	Earlsboro	Pen	S		y	y	y			
197		37										
198		36	Boggy		S		2,697	2,714	17			
199		38	Cromwell-Wilcox	Pen, Ord	S	Por	y	4,100	y	y		
200		36	Various	Pen, Ord	S	y	y	y	y	y		
201		39	Wilcox	Ord	S		4,378	4,380	2			
202		39	Hunton-Wilcox	Pen, Ord	LS		y	4,300	y			
203		38	Booch		S		3,034	3,054	20			
204		37	{ Gilcrease	Pen	S		y	y	y			
			{ Cromwell	Mis	S		3,261	3,290	29			
205		36	Various	Pen, Mis, Ord	S, L		2,793	4,187				
206		37	Wilcox	Ord	S	Por	4,047	4,050	3	y		
207		38	Hunton-Wilcox	Sil, Ord	LS	Por	4,120	4,325	y	y		
208		39	Cromwell	Mis	S		3,775	3,791	16	y		
209		32	Wilcox	Ord	S	y	4,596	y	y	y		
210		39	Wilcox (Simpson)	Ord	S	Por			y	y		
211		38	{ Cromwell	Mis	S		3,514					
			{ Hunton	Sil	L		y					
			{ Wilcox	Ord	S		y					
212		42	Wilcox	Ord	S	Por	4,085	4,115	30	A	Wilcox	4,150
213		36	Thurman		S		2,671	2,691	20			
214		36	Calvin		S		2,159	2,174	15			
215		36	{ Simpson	Ord	S		3,500	y	y			
			{ Wilcox	Ord	S		3,781	y	y			
216		33	Earlsboro		S		2,347	2,360	13			
217		37	Hunton	Sil	L		3,317	y	y			
218		35	Hunton	Sil	L		2,420	2,585	165			
219		37	Cromwell-Hunton Wilcox	Pen, Sil, Ord	SL	Por						
220		38	{ Hunton	Sil	L		y	y	y			
			{ Wilcox	Ord	S		4,214	y	y			
221		38	{ Calvin-Cromwell	Pen-Mis	L, S							
			{ Hunton-Wilcox	Sil-Ord	L, S							
222		40	Boggy-Wilcox		S		y	y	y			
223												
224		37.9										
225		32	Various	Pen	S	Por		2,100		AF	Ord lime	3,000
226		35	Woodford	Mis	S		4,170	4,324	154			
227		38	Viola	Ord	L		5,970	6,235	265			
228		39	Atoka		S		790	836	46			
229		34	Bromide and McLish		S		5,755	5,994	y			
230		37	Viola	Ord	L		3,485	3,623	138			
231		26	Arbuckle-Preston									
232		26	Sand		S		537	540	3			
233		26	Cretaceous-Trinity									
234		40	Trinity		S		402					
235		27	Boggy-Senora		S		1,790	1,795	5			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939	Number of Wells	
								Completed	Abandoned	Producing Oil[c]	Flowing	Artificial Lift
236	Allen (Shallow), *Pontotoc*	1913	*y*		8,456,337	112,420				192		192
237	Beebe, *Pontotoc*	1923	*y*		8,755,864	880,745		17		177		177
238	Beebe, East, *Pontotoc*	1930	*y*		204,035	102,200		2		22	*y*	*y*
239	Conservation, *Pontotoc*	1927	*y*		458,759	29,930				10		10
240	Fitts, *Pontotoc*	1933	5,580		82,877,500	8,868,040	989	26		856	*y*	*y*
241	Fitts, North, *Pontotoc*	1934	*y*		440,607	42,340				15		15
242	Fitts, South, *Pontotoc*	1937	320		269,928	109,135		11		23		23
243	Fitts, West, *Pontotoc*	1937	170		287,692	109,500				13		13
244	Francis, *Pontotoc*	1918	*y*		13,427	365				1		1
245	Francis, West, *Pontotoc*	1917	*y*		207,017	4,380				5		5
246	Jesse, *Pontotoc*	1935	*y*		3,467,032	816,140	*y*	4		68	*y*	*y*
247	Oakman, *Pontotoc*	1935	*y*		16,060	5,840				5		5
248	Steedman, *Pontotoc*	1934	*y*		15,118	1,460				1		1
249	Steedman, North, *Pontotoc*	1928	*y*		1,485,683	103,660		1		15		15
250	Remainder Southeastern Okla.				27,673	8,030				11		
251	Total Southeastern Oklahoma				112,615,293	11,401,870				1,725		
	Southwestern Oklahoma											
252	Binger, *Caddo*	1934	10		56,847	10,585	1			1		1
253	Cement, *Caddo*	1917	2,900		17,054,885	1,834,855	381	51		284	*y*	*y*
254	Ed Cox, *Carter*	1925	*y*		424,875	77,015		2		45		45
255	Fox (Old Prod.), *Carter*	1917	1,110	420	12,555,424	220,577				90		90
256	Fox (Deep), *Carter*	1935	320		1,179,425	389,703	8	1		8		8
257	Graham, *Carter*	1917	2,520	220	25,671,977	372,665				284		284
258	Healdton, *Carter*	1913	8,175		184,288,885	3,233,900	2,340	26		1,929		1,929
259	Hewitt, *Carter*	1919	3,500		86,162,510	1,353,785	913	2		766		766
260	Sholem-Alechem, *Carter*	1923	3,570	220	35,969,700	939,875	396	1		318		318
261	Tatums, *Carter*	1927	2,300		14,902,024	597,505	247			220		220
262	Tussy, *Carter*	1933	*y*		2,338,008	134,320				83		83
263	Wheeler, *Carter*	1916	540	160	40,399	2,190				75		75
264	Wildcat Jim, *Carter*	1914	*y*		16,638,283	189,435				88		88
265	Hanbury, *Comanche*	1920	*y*		42,685	2,190				7		7
266	Walters, *Cotton*	1917	*y*		24,792,771	352,590				253		253
267	Robberson, *Garvin*	1921	2,480	320	14,507,989	368,650	328			183		183
268	Knox, *Grady*	1924	2,050	250	13,648,023	600,790	245	8		157		157
269	Altus, *Jackson*	1934	770		835,933	195,640		29		64	*y*	*y*
270	Tipton, *Jackson*	1935	*y*		1,091,200	390,185		28		52	*y*	*y*
271	Oscar, *Jefferson*	1924	*y*		9,212,695	375,950				187		187
272	Seay, *Jefferson*	1924	*y*		490,795	20,805		2		49		49
273	Spring, *Jefferson*	1924	*y*		1,926,650	69,715				37		37
274	Hobart, *Kiowa*	1939	*y*		53,290	53,290		4		4	*y*	*y*
275	Stockton, *Love*	1937	*y*		30,160	10,950				1		1
276	Comanche, *Stephens*	1918	*y*		10,015,668	217,905		7		158		158
277	Cruce, *Stephens*	1926	*y*		60,191	7,300				5		5
278	Doyle, *Stephens*	1921	*y*		605,942	58,035		2		27		27
279	Doyle, West, *Stephens*	1939	*y*		25,185	25,185				1		
280	Duncan, North, *Stephens*	1920	*y*		3,943,965	147,825				93		93
281	Duncan, West, *Stephens*	1919	*y*		5,659,759	129,575				78		78
282	Empire, *Stephens*	1920	*y*		12,823,651	491,655		13		268		268
283	Loco, *Stephens*	1915	*y*		1,400,949	75,190		1		67		67

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
236		30	Various									
237		36	Boggy Hunton Viola	y Sil Ord	S L L		1,600 2,300 y	1,750 2,407 y	150 107 y			
238		35	Sand	y	S		1,830	1,839	9			
239		30	Boggy Hunton		S L		y 2,656	y 2,675	y 19		Wilcox	3,062
240	e1,980	39	Upper Simpson Hunton, Gilcrease Wilcox, Cromwell									
241		32	Gilcrease	Pen	S		1,767	y	y			
242		35	Gilcrease Hunton Viola	Pen Sil Ord	S L L		y 3,876 y	y 4,181 y	y 305 y			
243	e1,850	39	Cromwell	Mis	S		3,021	3,110	89			
244		26	Uncorrelated				1,200	2,000				
245		27	Allen-Senora									
246		40	Hunton McLish	Sil Ord	L S	y Por	3,884 4,620	3,910 4,633	26 13	AF		
247		29	Boggy		S		1,160	1,169	9			
248		31	Boggy (?)									
249		31	Boggy									
250												
251		38.6										
252		38	Binger	Pen	S	Por			y	y		
253		34	Various	Per, Pen	S		1,900	6,000				
254		22	Pen, Glenn	Pen	S		1,250	2,910	30			
255	500	31	Deese	Pen	S	30	2,200	2,500		A		
256		30	Simpson	Ord	S		7,950	8,037		AF	Simpson	8,105
257	750	31	Deese	Lower Pen	S	28–30			45–70	A	Dornicks Hills	5,180
258		31	Various	Pen, Ord	SL	Por	920	3,500		AF	Arbuckle	x
259		34	Various	Pen	S	15–20	920	2,700		AF	Arbuckle	x
260	760	29	Deese	Pen	S	30	1,890	4,000	40	A		
261	500	27	Deese-Dornick Hills	Pen	S	30			60	AMDL		
262		23	Deese	Pen	S	Por			y	A		
263	300	20	Pontotoc	Upper Pen	S	y				A		
264		24	Various				1,552	2,890				
265		38	Various				1,640	2,100				
266		34	Various				2,100	2,400				
267		23	Pontotoc-Simpson	Per, Ord	SL	y	y	1,200–1,900		A-AV		
268		35	Various	Per	S	15–20	1,700	2,200	15	AF		8,963
269		41	Granite Wash	Pen	S	Por			30	D		
270		40	Canyon, Reworked Arbuckle	Cam-Ord	L		y	y	y			
271		33	Glenn	Pen	S		1,180	1,610	25			
272		35	Various				1,100					
273		35	Hoxbar				2,095	2,101	6			
274		35	Lime		L		1,091	1,107	16			
275		35	Sand		S		6,893	6,927	34			
276		34			S		1,400	1,800				
277		30	Sand		S		800	1,900				
278		30	Uncorrelated				1,110	1,250				
279		42	Deese		S		5,578	5,614	36			
280		36	Various				1,700	2,300				
281		33	Various				1,700	2,300				
282		39	Various				1,600	2,300				
283		23	Glenn	Pen	S		850	1,550				

Production control was generally satisfactory. The average state allowable, as fixed by the Corporation Commission, was 425,000 bbl. daily as compared with the Bureau of Mines' average estimate of demand for Oklahoma crude of 455,000 bbl. daily. Production figures quoted above are figured on the basis of Corporation Commission reports, which generally are somewhat less than those reported by the Bureau of Mines. In any event, production was substantially less than the Bureau's estimate.

Probably the most important development with respect to conservation in Oklahoma was the decision of the United States Supreme Court dismissing an attack on the constitutionality of the Oklahoma well-spacing law. The law was enacted in 1937 and orders have subsequently been issued fixing 10-acre spacing in 32 pools, 20-acre spacing in 8 pools and 40-acre spacing in 6 pools.

Drilling activity increased slightly, resulting in the completion of 1921 wells. Of these, 1097 were oil wells with a combined potential of 408,000 bbl., 162 were gas wells initialing 688,000,000 cu. ft. and 662 were dry holes. Of the total completions, 190 were exploratory wells resulting in 30 oil discoveries, 5 gas discoveries and 155 dry holes.

Exploratory Drilling.—Wildcat effort met with meager success. While 30 discoveries were registered, comprising 21 new pools and 9 new

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods, End of 1939	
								During 1939		End of 1939	Number of Wells	
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Producing Oil[c]	Flowing	Artificial Lift
284	Milroy (deep), *Stephens*	1937	40		210,109	28,835				1	1	
885	Milroy (shallow), *Stephens*	1916	*y*		3,148,567	98,185		6		143		143
286	Palacine, *Stephens*	1929	*y*		130,650	14,235				7		7
287	Rainola, *Stephens*	1921	*y*		1,120,203	44,165				22		22
288	Velma, *Stephens*	1917	*y*		5,543,176	280,320		30		627		627
289	Woolsey, *Stephens*	1922	*y*		138,476	28,105				19		19
290	Frederick district, *Tillman*	1937	*y*		717,331	362,810		5		13	*y*	*y*
291	Red River Bed, *Tillman*	1920	*y*		2,622,841	140,160				90		90
292	Remainder Southwestern				629,819	12,775				6		
293	Total Southwestern				512,711,915	13,959,425				6,810		
	NORTHEASTERN											
294	(Washington, Nowata, Rogers, and Craig Counties)[7]				336,088,593	6,371,805				15,813		
295	TOTAL OKLAHOMA				4,616,678,495	153,605,385		1,261		55,495		

[7] Repressuring operations of secondary recovery type.

producing horizons in old pools, no new areas were proved where widespread exploitation can be expected.

Of chief importance was the number of deep tests drilled in western Oklahoma, the most interesting of which, perhaps, was that by the Continental Oil Co. in Washita County. This well, in C NW¼ sec. 28, 10 N., 20 W., was drilled to a depth of 14,582 ft., where it was abandoned because of inability to recover drill pipe lost in the hole. This is the deepest well ever drilled in Oklahoma.

In Kingfisher County, a small gas field was found by the Anderson Prichard Co. in sec. 15, 18 N., 9 W. from 7330 to 7350 ft. after drilling to a total depth of 8507 ft. Further interest in this test has been aroused by the fact that the operators have decided to drill the well to the Ordovician during the early part of 1940.

Among the discovery wells, probably the most important was the Gled Oil Co. and Russell S. Tarr's No. 1 Watkins, sec. 20, 7 N., 17 W., Kiowa County. Production was found in the Viola lime from 1049 to 1055 ft. The well was completed with a flowing potential of 100 bbl. an hour.

Of considerable importance to the industry in southern Oklahoma was the plugging back of an 8157-ft. Ordovician producer in the Milroy pool to the Hunton lime pay at approximately 4850 ft. The Ordovician pay was exhausted after the well had produced about 200,000 bbl. of oil.

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
	Initial	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
284		42	Oölitic				7,554	7,625	71			
285		26	Permian	Per			340	370	10			
			Unconformity	x			580	x	5			
			Glenn	Pen			1,060	x	25			
286		36	Arbuckle-Pen									
287		36	Smith	Pen			2,000	2,025	25			
			Brown				2,100	2,155	55			
288		26	Permian	Per			350	900				
			Glenn	Pen	S		1,700	2,300				
289		32	Permian	Per			1,300					
			Glenn	Pen	S		1,750	1,850	100			
290		44	Canyon		L		3,081					
			Strawn		S		4,215	4,218	3			
291		39	Cisco (?)				1,540	1,700	19			
292												
293		31.7										
294												
		36										
295		37.3										

After plugging back and acidizing of the Hunton limestone, the initial yield was 2067 bbl. Depleted wells in the near-by Fox pool, which also produced from the deep Ordovician pay, are likewise being plugged back to test the Hunton.

The recombing of old areas in the Greater Seminole section during 1939 resulted in considerable wildcatting. This endeavor opened several small producing areas. The greater part of this work was conducted by individual operators and small companies.

It is expected that 1940 wildcatting in Oklahoma will continue in much the same trend as in 1939. Extreme southern Oklahoma and the northwestern part of the state are expected to be the two areas arousing most interest.

TABLE 2.—*Summary of Drilling Operations in Oklahoma*

Important Wildcats Drilled in 1939

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	McClain	6	5 N	2 E		Permian	Simpson
2	Osage	10	28 N	11 E	993	Pennsylvanian	Peru sand
3	Garfield	36	22 N	4 W	5,046	Permian	Simpson
4	Oklahoma	30	11 N	1 E	6,638	Permian-Penn.	Simpson
5	Stephens	4	1 N	5 W	5,620	Permian	Pennsylvanian
6	Grady	26	5 N	8 W	6,613	Permian	Pennsylvanian
7	Garfield	26	24 N	8 W	7,110	Permian	Simpson
8	Cleveland	23	8 N	2 W	8,008	Permian	Simpson
9	Seminole	34	10 N	6 E	4,630	Permian-Penn.	Simpson
10	Hughes	1	6 N	10 E	6,153	Pennsylvanian	Simpson
11	Payne	26	18 N	4 E	3,833	Permian-Penn.	Simpson
12	Osage	26	25 N	6 E	2,931	Permian-Penn.	Mississippian
13	Carter	35	3 S	1 E	8,500	Pennsylvanian	Simpson
14	Okmulgee	34	14 N	10 E	3,296	Pennsylvanian	Simpson
15	Tillman	36	2 S	19 W	5,141	Quaternary	Simpson
16	Kiowa	20	7 N	17 W	1,055	Permian	?
17	Logan	12	17 N	1 W	5,177	Permian-Penn.	Simpson
18	Stephens	24	2 S	4 W	8,157	Permian	Simpson
19	Okmulgee	10	13 N	10 E	2,685	Pennsylvanian	Dutcher sand
20	Wagoner	30	17 N	18 E	760	Pennsylvanian	Pennsylvanian
21	Washita	28	10 N	20 W	14,582	Permian	Pennsylvanian
22	Pontotoc	16	5 N	3 E	3,685	Pennsylvanian	Viola Ls.
23	Grant	29	25 N	8 W	6,649	Permian	Simpson
24	Canadian	16	14 N	9 W	9,611	Permian	Pennsylvanian
25	Cleveland	17	9 N	2 W	7,696	Permian	Simpson
26	Lincoln	24	12 N	3 E	5,504	Permian-Penn.	Simpson
27	Oklahoma	28	13 N	1 E	6,058	Permian-Penn.	Simpson
28	Payne	30	19 N	2 E	4,851	Permian-Penn.	Simpson
29	Hughes	23	6 N	8 E	2,675	Pennsylvanian	Booch sand
30	Pottawatomie	36	10 N	4 E	4,532	Permian-Penn.	Hunton Ls.
31	Payne	24	18 N	1 E	5,066	Permian-Penn.	Simpson
32	Kingfisher	15	18 N	9 W	8,507	Permian	Mississippian
33	Pontotoc	27	5 N	4 E	2,639	Pennsylvanian	Hunton Ls.
34	Pottawatomie	31	10 N	5 E	4,485	Permian-Penn.	Simpson
35	Seminole	19	6 N	5 E	4,062	Pennsylvanian	Simpson
36	Noble	9	21 N	2 E	4,533	Permian-Penn.	Simpson
37	Garfield	21	24 N	4 W	6,326	Permian	Simpson?
38	Cleveland	24	6 N	1 E	6,387	Permian	Simpson
39	Noble	34	20 N	2 W	5,074	Permian	Simpson
40	Harper	5	27 N	23 W	7,420	Permian	Mississippian
41	Grant	4	25 N	3 W	5,528	Permian	Simpson
42	Seminole	3	5 N	5 E	2,668	Pennsylvanian	Hunton
43	Pittsburg	11	7 N	15 E	7,731	Pennsylvanian	Simpson
44	Hughes	8	4 N	9 E	6,333	Pennsylvanian	Simpson

Water-flooding.—Eight permits for water-flood projects were issued by the Corporation Commission during the year. Seven were in the shallow northeastern area, which has had relatively extensive development of this type in the Bartlesville sand at 600 to 1000-ft. depths. The other was a pioneer effort in Creek County, where the application was for flooding the Skinner sand at about 2100 feet.

Ramsey Field.—From a standpoint of initial production, the Ramsey pool, sec. 13, 18 N., 1 E. and 7 and sec. 18, 18 N., 2 E., Payne County, took first rank with 140,000-bbl. initial from 20 successful completions. From the date of discovery, Jan. 12, 1938, production has been sharply curtailed. During 1938 the pool produced 537,000 bbl. and the current year's production amounted to 1,483,000 bbl., making a total recovery of

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		
1	I.T.I.O.				Dry hole
2	Charles Petr. Corp.	102		Pump	Peru sand well, 947–92
3	Kerlyn Oil Co.				Dry hole
4	R. Olsen et al.	175		Flow	Hunton lime well, 6004–95
5	Phillips Petr. Co.	1,071		Flow	Deese sand well, 5578–5614
6	The Carter Oil Co.		13		Deese sand well, 5330–50
7	Champlin Ref. Co.				Dry hole
8	Harper-Turner				Dry hole
9	H. S. Moss	614		1/32″ choke	Cromwell sand well, 3812–20
10	Phillips Petr. Co.				Dry hole
11	Mulberry Oil Co.	155		Flow	Wilcox sand well, 3820–33
12	I.T.I.O.	10		Pump	Skinner sand well, 2732–51
13	Pure Oil Co.	190		Pump	Sycamore ls. and Woodpeck sh. well
14	W. M. Dunn et al.	460		Flow	Pool produces from Misener and Wilcox
15	I.T.I.O.	150		Pump	Simpson well, 5134–41
16	Gled Oil Co. et al.	1,600		Flow	Pontotoc footwall well
17	Stanolind-Amerada	10		Pump	Marshall Zone well, 5133
18	Carter Oil Co.	320		Flow	Hunton Lime well, 4845–75
19	Hyer and Kirchner	144		Flow	Dutcher sand well
20	Shirley et al.	35		Pump	Producing zone, sand 748–60
21	Continental Oil Co.				Dry hole
22	Patsy Oil Co.	1,000		1/4″ casing choke	Viola lime producer
23	Magnolia Petr. Co.				Dry hole
24	W. R. Ramsey				Dry hole
25	Nels Burton et al.	125		Pump	Upper Simpson producer 7484–7695
26	Summit Drilling Co.				Dry hole
27	Hall & Briscoe				Dry hole
28	Kirk-Greenway Drilling Co.				Dry hole
29	Stanley Rogers et al.	35			Booch sand producer, 2648–70
20	S. D. Butcher	1,084		1/2″ tubing choke	Hunton producer
31	Blackwell Oil & Gas				Dry hole
32	Anderson-Prichard & Mag.	10	3		PB 7365 acidized lime pay 7330–50
33	Grisso and Eason	50		Pump	Treated Hunton pay 2476–2621, 3000 gal.
34	George Pace et al.	800		Flow	Treated Viola pay 4374–4416, 2000 gal.
35	Alma Oil Co.	230		Pump	Producing from Earlsboro sand, 2890–2900
36	Shell Petr. Co.				Dry hole
37	Gulf Oil Corp.				Dry hole
38	Hall and Briscoe				Dry hole
39	Amerada et al.				Layton sand, 3980–4020 (Heald W sand area)
40	Sinclair-Prairie				Dry hole
41	Carter Oil Co.				Dry hole
42	Culver et al.	450		Flow	Hunton lime producer, 2662–68
43	Phillips Petr. Co.				Dry hole
44	Continental Oil Co.				Dry hole

2,020,000 bbl. to the end of 1939. Oil is from the Wilcox sand at a depth of approximately 4800 feet.

St. Louis Field.—Contrary to the general trend, the St. Louis pool, Pottawatomie County, increased its yield over 1938. It produced 11,302,000 bbl., the highest figure it has attained since its peak year, 1930, when 11,607,000 bbl. was produced. The St. Louis pool was the most actively exploited in the state during the year, there being 223 completions, of which 185 were oil wells, averaging 300 bbl. initial, 4 were gas wells, averaging 5,000,000 cu. ft. initial, and 34 were dry holes.

Cement Field.—In Caddo County, southwestern Oklahoma, the Cement pool attracted considerable interest. Forty-four oil wells with an average initial of 1250 bbl., seven gas wells averaging an initial of 11,700,000 cu. ft. and nine dry holes were completed during the year. Although voluntary proration of production was applied to this pool last October, a total of 1,835,000 bbl. was produced compared with 1,315,000 bbl. during 1938. December production averaged 6363 bbl. daily from 284 wells. The most prolific production of the present development campaign is coming from a sand designated locally as the "Rowe," at a depth of 3400 feet.

Billings Field.—In the Billings pool, Noble County, three oil wells were completed with a combined initial of 7878 bbl. Under restricted production, the pool produced 2,171,000 bbl. during the year, accumulated production to the end of 1939 amounting to 6,805,000 bbl. Oil is from the Wilcox sand, which was discovered in November 1935 at a depth of 4260 ft. Development is believed to be practically completed with one well drilling at the close of the year. The deep sand (Wilcox) is being efficiently exploited under community operation embracing a pressure-maintenance program.

Coyle Field.—Twenty-three oil wells with an average initial of 490 bbl. were completed in the Coyle pool, T. 17 N., 1 E., Payne County. This pool was discovered during the latter part of 1938, production coming from the Wilcox sand at 4850 ft. With production restricted throughout the year, 389,455 bbl. was produced.

Oklahoma City Field.—Only 14 oil wells with an average initial of 206 bbl., one gas well initialing 1,200,000 cu. ft. and eight dry holes were completed in the Oklahoma City pool during the year. There has been considerable reconditioning and plugging back to shallower oil and gas horizons, although the various Simpson pay zones continue to yield practically all of the production. Rated potential of the pool dropped from 341,714 bbl. on Jan. 1, 1939, to 154,020 bbl. on Jan. 1, 1940, or 55 per cent. Production under partial proration amounted to 35,700,000 bbl., a decrease of 7.9 per cent from the previous year. With only five wells drilling at the close of the year, it is believed 1940 will see development completed and the pool producing to capacity. Discovered in

December 1928, total recovery to the end of 1939 amounted to 478,760,000 barrels.

Fitts Field.—Production in the Fitts pool continues to decline at a rapid rate. In 1937, its peak year, production amounted to 30,628,000 bbl. In 1938, the pool produced 16,403,000 bbl., a decline of 46 per cent, and in 1939 production again declined 46 per cent; that is, to 8,868,000 bbl. At the end of 1937, there were 892 wells producing; at the close of 1938, there were 877 and on Dec. 31, 1939, the number was 856. Twenty-six oil wells were completed during the year with an average initial of 700 bbl. The pool is fully developed and production can be expected to continue its downward trend but more slowly.

Sac and Fox Field.—In this pool, centering around sec. 15 and sec. 16, 14 N., 6 E., Lincoln County, 31 oil wells were completed with an average initial production of 79 bbl. Production is from the Prue sand at a depth of approximately 3000 ft. Total production for the year amounted to 1,109,235 bbl., the pool's peak year.

Oil and Gas Development in Northern and Central Pennsylvania during 1939

By Arthur C. Simmons,* Member A.I.M.E.

(New York Meeting, February 1940)

Oil production and activity in northern and central Pennsylvania was slightly less in 1939 than in the previous year, but owing to higher average prices 1939 was undoubtedly a better business year. The last quarter showed markedly increased activities throughout all of the Pennsylvania fields.

Production, Stocks and Price

Storage of Pennsylvania crude oil at pipe lines and refineries totaled 5,443,000 bbl. on Dec. 31, 1938, and declined during the year 1,124,000 bbl. to a total of 4,319,000 bbl. at the end of 1939. The stocks of crude at the end of the year represent the lowest point reached in Pennsylvania-grade crude storage in recent years. Stocks increased slightly during April, May and June, but decreased during all other months of 1939.

The Bradford field production within the state of Pennsylvania averaged 35,340 bbl. per day throughout 1939, which represents a decrease of 1419 bbl. a day from the 1938 average. The production in central and southern Pennsylvania increased 1176 bbl. per day, averaging 12,159 bbl. throughout 1939.

Table 1 includes annual production for the part of Bradford field situated within the state of Pennsylvania, for central and southern Pennsylvania, and for the entire state of Pennsylvania. A definite segregation of production between the Bradford field and central and southern Pennsylvania is slightly ambiguous because a portion of the oil from the newly discovered Music Mountain pool is included statistically in each area. In all probability the entire increase and some small addition to the production from southern Pennsylvania can be attributed to oil produced from the Music Mountain pool.

Within the Bradford field, six price changes occurred throughout the year. At the beginning of 1939 the price of Bradford crude oil was $1.80 per barrel, whereas by the end of the year it had risen to $2.50. The weighted average price for Bradford crude during 1939 was $2.059 per barrel.

Summarized at meeting. Manuscript received at the office of the Institute April 16, 1940.

* Consulting Engineer, Bradford, Pa.

DRILLING

Table 1 shows the number of wells completed within the Bradford field for the years 1937, 1938 and 1939. Oil production in the Bradford field can be segregated into the Pennsylvania end of the Bradford field and the New York state portion of the Bradford field, whereas it is necessary in comparing well completions to include the entire Bradford field, which is situated in both states. Well completions decreased slightly; 2114 wells were drilled in 1939 as compared with 2148 in 1938. Two factors contributed toward the moderate number of well completions: (1) the excess crude that could be produced from the Music Mountain pool, and (2) the excessive drilling of 1937 had not been fully liquidated. There was a marked increase in well completions during the last three months of 1939 and it would appear that the approximate rate of 250 wells per month, which occurred during the last quarter, would prevail throughout the greater part of 1940. Data on well completions include wells drilled as water-intake wells and oil-producing wells, and approximately half of the total were oil wells.

TABLE 1.—*Oil Production, State of Pennsylvania*

Year	Wells Completed, Bradford Field[a]		Oil Production, Bradford Field[b]		Oil Production, Central and Southern Pennsylvania		Oil Production, State of Pennsylvania	
	Number	Change	Barrels	Change	Barrels	Change	Barrels	Change
Total:								
1937.....	4,112		15,076,909		4,108,100		19,185,109	
1938.....	2,148	1,964−	13,417,102	1,659,807−	4,008,923	99,177−	17,426,025	1,758,984−
1939.....	2,114	34−	12,899,104	517,998−	4,438,035	429,112+	17,337,139	88,886−
Daily average:								
1937.....			41,300		11,255		52,555	
1938.....			36,759	4,541−	10,983	272−	47,742	4,813−
1939.....			35,340	1,419−	12,159	1,176+	47,499	243−

[a] Includes oil and water intake wells and New York State part of Bradford field.

[b] Pennsylvania production only.

MUSIC MOUNTAIN FIELD

The Music Mountain field was discovered in the fall of 1937 and represents a new pool with flowing wells. It is about 9 miles southwest of the city of Bradford and in all probability represents a shore-line deposit. The productive area is reasonably well defined although an additional extension to the southwest is still possible. It represents a long, narrow streak of productive formation about 3½ miles long and, in some instances, less than 1000 ft. wide. Some few wells, representing the larger producers, have produced during the first few hours at a rate of 400 to 500 bbl. per hour. The field was severely prorated, by mutual agreement of the operators, during the greater part of 1939, but during the last quarter the rate of production was increased and for short periods of time was 5000 to 6000 bbl. per day.

The Music Mountain pool includes about 600 proven acres, and drilling to date has resulted in the following: dry holes, 39; gas wells, 11; flowing wells, 63; pumping wells, 31; total wells drilled, 144. Many of the dry holes were outside of the now defined productive limits of the field.

The producing horizon is Devonian, about 250 ft. above the Third, or Bradford, sand. This horizon can probably be correlated with the white Cooper sand although locally it has been designated as the Sliverville sand.

Oriskany Gas Production

No new gas fields were opened in the Oriskany horizon in Pennsylvania during 1939, although rapid exhaustion and depletion of the old fields led to the drilling of a large number of unsuccessful wildcat tests.

New Developments

Virtually all of the oil production in the Bradford area is obtained by water-flooding methods. In central and southern Pennsylvania production is obtained from natural stripper wells and by air and gas repressuring. About 500,000 bbl. of oil was obtained from flowing wells in the Music Mountain pool during 1939.

Because of insufficient supplies of gas for fuel on intensive water-flood developments, there has been a decided trend toward "closed systems" wherein buried lead lines conduct oil and water from individual wells to a common gravity separator as substantial quantities of gas can be recovered and used as fuel. This system possesses many meritorious features and in some instances it has been reported that an increase in production was caused by eliminating evaporation at individual receiving tanks.

Paralleling the shortage of fuel, there has occurred a decided trend toward the use of individual electric pumping jacks. Many of these jacks are equipped with automatic time clocks, permitting wells to be pumped several periods during the day.

Higher applied water pressures are gradually becoming common as it is demonstrable that higher pressures will yield greater ultimate recoveries.

The usual emphasis was placed on water conditioning and treatment and a few installations have deen made using catalytic filters for the removal of iron and manganese.

It appears probable that 1940 will see the completion of many more wells in the Bradford field than did 1938 or 1939. Such increased activty will depend on economic conditions in the industry but it appears certain that the excess production resulting from excessive drilling in 1937 has been thoroughly liquidated.

Oil and Gas Developments in Southwestern Pennsylvania during 1939

By John T. Galey,* Junior Member A.I.M.E.

(New York Meeting, February 1940)

In all, 210 wells† were completed in southwestern Pennsylvania during 1939, which is 59 more than were drilled during the preceding year. Of this number, 137 were gas wells, which is a considerable increase from the 81 completed during 1938. Only 25 oil wells were completed, as against 28 in the previous year, and 28 dry holes, 6 more than last year.

SHALLOW DEVELOPMENT—GAS

The increase in the number of gas wells is largely the result of a search for additional gas in Armstrong and Indiana Counties. Although a considerable number of wells were drilled in the latter county, the majority of them produced less than 100 M cu. ft. initial open flow. In Armstrong County, a new pool was opened in Cowanshannock township, producing from the third Bradford sand. Several large wells were obtained there, one of which produced an initial of nearly 12 million cu. ft., with a reservoir pressure of 1100 lb. However, the productive area has been fairly well outlined by further drilling and shows that the pool covers only about 800 acres. The sand is 20 to 30 ft. thick, and probably has 5 to 6 ft. of pay. Thus this reserve is not an important one. Several wells were found in Menallen township, Fayette County, where the Big Injun sand has been having a play for the past three years, but the activity there is much less than a year ago.

OIL

On the west side of the Bradford sand gas pool, Cowanshannock township, Armstrong County, a well was drilled which flowed 100 bbl. the first day from the Tiona sand. The probability is that this well is a freak, as the Tiona has been drilled within a fairly close distance on every

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Summarized at meeting; manuscript received at the office of the Institute April 17, 1940.

* Oil and Gas Operator, Pittsburgh, Pa.

† This figure includes both drilling and deepening of wells in the counties of Allegheny, Armstrong, Beaver, Butler, Greene, Washington, and parts of Fayette and Indiana.

side and has showed no oil. This occurrence, however, is notable in view of the fact that it is approximately 20 miles east of the area in which oil ordinarily is found. There was no other new oil productive area found during 1939. The 25 productive wells drilled in proven areas resulted in total initial production of 241 bbl., which is 36 bbl. more than was developed by 28 wells during 1938.

At the beginning of 1939, southwestern Pennsylvania crude was selling for only $1.34 per barrel. Seven increases occurred during the year, which resulted in a price of $2.40 per barrel by the end of the year. With the increase in price, drilling activity increased, as more than 60 per cent of the wells completed were drilled during the last six months of the year.

TABLE 1.—*Oil Production Data for Southwestern Pennsylvania during* 1938[a]

County	Production, Bbl.	Wells Connected as of Dec. 31, 1937	Wells Connected during 1938	Wells Disconnected during 1938	Wells Connected as of Dec. 31, 1938
Allegheny	254,613.56	1,299	18	66	1,251
Armstrong	21,270.39	251	1	3	249
Beaver	37,695.13	609	4	37	576
Butler	446,833.64	5,133	59	170	5,022
Greene	242,266.45	742	10	15	737
Lawrence	12,089.68	541	2	7	536
Washington	432,978.49	1,699	5	34	1,670
Westmoreland	86.81				
	1,447,833.95	10,274	99	332	10,041

[a] Commonwealth of Pennsylvania, Department of Internal Affairs, *Monthly Bulletin* (1940) **8**, No. 4, 30.

DEEP-SAND DEVELOPMENT

While deep-sand drilling activity was receding with only five wells completed to the Onondaga, or Oriskany (L. Dev.) there were three important developments. The Heyn No. 1 well, on the Chestnut Ridge anticline, South Union township, Fayette County, was deepened 20 ft. into the Onondaga to a total depth of 6687 ft., and production increased from 1.25 to 6.9 million cu. ft. The Oriskany sand has not been reached in that well. On the west flank of the Chestnut Ridge anticline, the recently completed Piedmont Coal No. 1 well, although 233 ft. structurally lower than the Heyn No. 1 well, has found over 4 million cu. ft. in the Onondaga, and demonstrated the fact that this horizon will produce well down on the flanks of the structure. The Lowry Martin No. 1 well, Wayne township, Armstrong County, proved dry after being drilled to a depth of 6889 ft., or 318 ft. below the top of the Onondaga, and finding only 2 ft. of sand. This well aids in defining the southern boundary of the Oriskany "No Sand area" of northern Pennsylvania.

Two wells are drilling to the Onondaga in Fayette County: namely, the J. H. Sorg No. 2, on the Chestnut Ridge anticline, and the Gregg L. Neel No. 1, on the Laurel Hill anticline, in Stewart township. The latter well is being watched with considerable interest, as it will be the southeasternmost well in southwestern Pennsylvania to penetrate the Onondaga.

In the Black Hawk pool, South Beaver township, Beaver County, the James Tennis Heirs No. 1 well, which has produced gas from the Oriskany for several years, is being prepared to be deepened to the Medina sand. This well is the first to test the Lockport dolomite and Clinton (Sil.) on proven Oriskany structure in southwestern Pennsylvania.

TABLE 2.—*Deep Drilling in Southwestern Pennsylvania during* 1939

County	Township	Well	Elevation, Ft.	Depth, Ft.				Remarks
				Tully	Onondaga	Oriskany	Total	
Armstrong....	Wayne	Martin No. 1	1,585	6,120–6,193	6,558[a] 6,571[b]	6,681–6,683	6,889	Oriskany sand poor. Abandoned
Beaver.......	Rochester	Linnenbrink No. 1	889	4,777–4,806	4,978[a]	5,143–5,179	5,295	S.W.[d] Abandoned
Butler........	Concord	Fowler No. 1	1,236	5,084–5,154	5,341[a]	5,448–5,458	5,549	Dry. Abandoned
Fayette......	N. Union	Piedmont Coal & Coke No. 1	2,178	6,060–6,190	6,692[b,c]		6,800	4 million cu. ft.
Fayette......	Spring Hill	Dunham No. 1	2,199	6,627–6,705	7,508[a]	7,698–7,771	7,826	Show gas at 7609. Abandoned
Fayette......	N. Union	Sorg No. 2						Shut down 2400
Fayette......	Stewart	Neel No. 1	2,566					Drilling 6533. No Tully

[a] Top of lime.

[b] Top of chert.

[c] Producing horizon.

[d] Salt water.

GAS POCKETS

Highly explosive gas pockets, which apparently are of high pressure and small volume, have offered a serious impediment to drilling the zone extending from a short distance above the Tully limestone to the Onondaga limestone throughout the area with the exception of the Chestnut Ridge and Laurel Hill anticlines. Tools have been blown up the hole as high as 500 ft. and wedged so tightly that it has been impossible to extricate them without cutting the line and fishing them out. On a number of occasions it has been necessary to drill past the stuck tools before they could be recovered. One of the early wells to encounter difficulty with gas pockets was the Charlotte R. Calvin No. 1, South Beaver township, Beaver County. This was the first well to produce Oriskany gas commercially in southwestern Pennsylvania. When this well was drilled into the Oriskany sand nearly 1 million cu. ft. of gas was encountered, together with 4 bbl. of saturated brine per day. The production string had not been set and the caving gas-pocket zone had not been thoroughly cemented. When the production string was ready to be run nearly 2000 ft. of Oriskany brine was being agitated by the gas in the hole, and it was found that practically no caving had resulted. It had also been observed in the Clinton fields of Ohio that a shale immediately above the "Little Lime" which ordinarily caved badly would stand up when brine rather than fresh water was employed as drilling fluid.

Thus at the time the James Tennis Hrs. No. 1 was drilled the experiment of carrying a column of Oriskany brine in the hole in order to lessen the explosive effect of the gas pockets was attempted. The brine used was taken from the Charlotte R. Calvin No. 1 well. This experiment proved a success and was described in TRANSACTIONS in 1937.

Since that time improvements have been made in the technique employed. A column of only 200 ft. of brine is dumped into the hole a short distance above the Tully limestone and drilling is carried on with stem of the same size used in drilling to this point, and with an ordinary bit rather than one of enlarged water course, which was used in the original experiment. After each run one bailer of the brine, which has become muddy, is removed and one bailer of fresh brine is added. Once each 24 hr. the brine is completely removed and a fresh solution is put in. It is recommended that when drilling to the Onondaga at depths in excess of 6000 ft. a column of 300 ft. or more be carried in the hole. It has been possible by this method to make an average of 50 ft. of new hole every 24 hr. through the caving gas-pocket zone. When a gas pocket is encountered the gas escapes through the column of brine slowly, from 5 to 15 ft. of cavings fall into the hole, and ordinarily are drilled up without pulling the tools. Consequently, on wells where this method has been employed, no difficulty has been experienced with gas pockets and there has been no loss of time caused by fishing jobs.

OUTLOOK

The search for gas in the Onondaga limestone on Chestnut Ridge and Laurel Hill should continue, as there is a major reserve indicated on the former and possibility of discovery of a major reserve seems promising on the latter. Completion costs on the Chestnut Ridge wells have been cut considerably, so that some profit should be made providing too many dry holes are not drilled.

While the search for Oriskany production has yielded only one small pool and indications of a second in southwestern Pennsylvania, the picture is not discouraging, for only two of the dry holes drilled were favorably located on structures suitable for Oriskany production. One of these wells had only 2 ft. of poor sand and the other may possibly have penetrated the Oriskany on the downthrown side of a fault, as the core showed the sand to be highly metamorphosed. Since the Oriskany "No Sand area" of northern Pennsylvania probably covers only a portion of northwestern Indiana and northeastern Armstrong Counties, and all other wells drilled in southwestern Pennsylvania have shown a considerable sand thickness, the possibilities have scarcely been touched, as there are a number of structures that seem favorable for accumulation. However, exploration of these Oriskany possibilities will no doubt be slow in coming about for although the shallow gas reserves in southwestern Pennsylvania are deficient gas can be imported at a cost low enough to keep the price down below the point at which profit can be made from deep-sand development. Thus the primary requisite for deep-sand exploration is a higher price for gas. Of equal import is a form of unit operation agreement between the owners of the various leaseholds, in order to confine drilling to the minimum number of wells that will effect the maximum recovery. This is necessary not only in view of the great depth that must be attained in order to reach the Oriskany, but also in view of the fact that probably most of the structures favorable to Oriskany accumulation are faulted and should have as many as three wells in order to be condemned.

Oil and Gas Development in the Rocky Mountain District in 1939

By C. E. Shoenfelt,* Member A.I.M.E.

(New York Meeting, February 1940)

The year 1939 witnessed the rapid development of several of the more important Rocky Mountain oil and gas areas and the discovery of new oil and gas fields. As a further result of an active year, many oil fields had their productive limits greatly extended or responded to deeper drilling with oil production in lower horizons.

In Colorado there was a substantial increase in refinery capacity, with three new units constructed. Its contribution to the crude-oil supply was an important extension of the producing area of a Western Slope field and a deeper oil-producing horizon in an old field east of the Front Range. Occurrences of gas were reported in two wells in northwestern Colorado, but severe winter weather prevented tests and the value of these discoveries cannot be determined at this time.

Montana's northern fields were extended and a number of record wells were completed. The North Cut Bank area gives promise of wide expansion in 1940. The gas-producing area of Wyoming's Elk Basin field was extended into Montana on the north plunge of the anticline.

The most important developments in Wyoming oil fields in 1939 were extensions to the producing area of Lance Creek and the discovery of a deeper pay in the Tensleep formation at Wertz dome. A new gas field at Horn Valley in the south central part of the state was the only new field discovered, but wildcatting was at low ebb in Wyoming in 1939.

COLORADO

In Colorado, the year 1939 saw the completion of several interesting tests, but largely with negative results. Oil was discovered, however, in a deeper sand in the old Fort Collins field and the productive area of the Wilson Creek field was extended. Gas had been noted in two Western Slope wells, at Yellowjacket-Buford and at Trull, but their volumes had not been determined at the end of the year. Of principal interest, however, were the failures, descriptions of which will be given presently. One of these established a new depth record for Colorado.

Summarized at meeting; manuscript received at the office of the Institute April 25, 1940.

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TABLE 1.—*Oil and Gas Production in Rocky Mountain District*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
	COLORADO					
1	Berthoud, *Larimer*	1927	510		54,182	3,840
2	Boulder, *Boulder*	1902	400		645,379	6,317
3	Florence, *Fremont*	1862	9,000		13,513,428	57,770
4	Ft. Collins, *Larimer*	1923	400		2,130,417	40,178
5	Garcia, *Las Animas*	1927		640		
6	Greasewood, *Weld*	1930	200		454,833	6,505
7	Hamilton, *Moffat*	1924	400		5,562,678	112,456
8	Hiawatha, *Moffat*	1928		3,180		
9	Iles, *Moffat*	1924	600		7,937,641	736,524
10	Model, *Las Animas*	1929		4,380		
11	Rangely, *Rio Blanco*	1919	320		523,258	34,613
12	Thornburg, *Rio Blanco*	1925		350		
13	Tow Creek, *Routt*	1924	200		1,637,605	52,903
14	Walden, *Jackson*	1927	320		156,886[1]	0
15	Wellington, *Larimer*	1924	1,000		4,778,081	75,234
16	Price, *Archuleta*	1934	200		554,537	217,344
17	Wilson Creek, *Rio Blanco*	1938	320		179,655	129,506
	WYOMING					
1	Alkali Butte, *Fremont*	1928	40	300	5,670	0
2	Allen Lake, *Carbon*	1933		200		
3	Ant Hills, *Niobrara*	1928	40		8,719	
4	Badger Basin, *Park*	1931	300		483,201	9,120
5	Baxter Basin (South), *Sweetwater*					
6	Frontier	1922		7,467		
7	Dakota	1922		4,310		
8	Baxter Basin (North), *Sweetwater*					
9	Dakota	1926		1,280		
10	Sundance	1928		2,280		
11	Beaver Creek, *Fremont*	1937		640		
12	Big Muddy, *Converse*	1915			26,163,187	453,870
13	Shannon	1916	2,000			
14	Wall Creek	1916				
15	Dakota	1922				
16	Big Sand Draw, *Fremont*					
17	Wall Creek	1917		1,200		
18	Lakota	1930		300		
19	Billy Creek, *Johnson*	1921		1,200		
20	Black Mountain, *Hot Springs*	1925	300	300	235,654	0
21	Bolton Creek, *Natrona*	1920			2,710	0
22	Sundance	1920	50			
23	Embar	1920	50			
24	Boone Dome, *Natrona*	1920		300		
25	Bunker Hill, *Carbon*	1936		480		
26	Byron Dome, *Big Horn*	1906			3,851,596	543,109
27	Frontier	1922		500		
28	Sundance	1929	40			
29	Embar-Tensleep	1932	2,950			
30	Cole Creek, *Natrona*	1937	*x*		47,962	24,801
31	Dallas-Derby, *Fremont*	1883	350		2,777,487	172,339
32	Dewey Dome, *Weston*	1936	40		19,004	2,090

[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Wells produce large quantities of CO_2 gas with the oil—shut in.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939			Number of Wells		Initial	Avg. at End of 1939		A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
				Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
COLORADO															
1	6,257	510	6				1	1		3	600	80		38.5	0.1
2			55				11			8				38.6	0.2
3			1,205	2		2	107			109				31	0.1
4			16	1			8			7				37	0.1
5	6,528	821	16					6			12	[3]			
6			8				1			1				42	0.1
7			23				12			12				41	0.1
8	161,337	19,190	11	1				10	2						
9			40	1			35			33				37	0.1
10	645	0[2]	8								12	Shut in			
11			74	14	8	1	8			8				43	0.1
12	1,658	890	4		1			3			725	y			
13			17				15			5				35	0.1
14			5											50	0.1
15			32				11			11				37.4	0.1
16			20				9			10				40	0.1
17			2	1		1	2		2					46	0.1
WYOMING															
1			3	0	0	0	0	3	0	0	y	y		37	
2	825.8	6.8	7	0	0	0	0	4	0	0	920	450			
3			3	0	1	0	0	0	0	0	0	0		35	
4			5	1	0	1	5	0	1	0	y	y		48	
5		4,260	26	2	0	0	0	25				0			
6											800				
7	23,912										815				
8		1,509	8	1	2	0	0	6	0	1					
9											1,335				
10											1,485				
11	0	0	1	0	0	0	0	1	0	0	2,500	2,500			
12			174	0	0	0	149	0	0	149	0	0		33.5	
13															
14															
15															
16	54,695	4,000	12	1	0	0	0	12	0	0					
17											1,300	680			
18											1,860	0			
19	3,014	310	10	1	0		0	9			1,150	400			
20			6	0	0	0	6	0	0	6	x	x		19	
21			14	0	0	0	3	0	0	3	x	x		22	
22															
23															
24	4,072	0	4	0	0	0	0	2			750	180			
25	89.2	89.2	5	0	0	0	0	2	0	0	500	500			
26			19	0	1	0	15	2	0	15				20	
27											1,000	350			
28											x	x			
29											x	x			
30			2	0	1	0	1	0	1	0	0	0		32.7	
31			72	0	0	0	42	0	0	42	x	x		Dallas 23.2 Derby 22.3	
32			4	0	1	0	1	0	0	1	x	x		31	

[2] Inert: contains 7.9 per cent helium.

[3] Operates under 19 points vacuum.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	COLORADO									
1	Hygiene	CreU	S	20	2,920	2,940	20	A	Lakota (CreL)	4,031
2	Pierre	CreU	H		2,000			MF	Morrison (Jur)	3,497
3	Pierre	CreU	H		2,200			TS	Fountain (Pen)	1,875
4	Muddy-Dakota	CreU	S	12	4,535	4,560	25	A	Dakota (CreU)	4,995
5	Benton	CreU	H		1,600			D	Fountain (Pen)	2,500
6	Muddy	CreU	S	9			35	A	Morrison (Jur)	7,040
7	Dakota	CreU	S	18	3,860	3,880				
	Sundance	Jur	S	14			20	D	Sundance (Jur)	4,480
8	Wasatch	Eoc	S	*y*	Sand lenses		*x*	D	Mesa Verde (CreU)	7,577
9	Sundance	Jur	S	9	3,295	3,315	20	D	Sundance (Jur)	3,447
10	Santa Rosa(?)	Tri	S	19	960	1,004	50	D	Fountain (Pen)	2,010
11	Mancos		H		600			A	Mississippian	7,173
	Dakota	CreU	S	15			35			
12	Sundance	Jur	S	15	1,975 2,525	2,125 3,050	500	D	Sundance (Jur)	3,110
13	Mancos	CreU	H		2,600			A	Gneiss[1]	5,310
14	Muddy-Dakota	CreU	S	14	5,110	5,215	90	AF	Morrison (Jur)	5,258
15	Muddy-Dakota	CreU	S	12	4,480	4,500	20	A	Sundance (Jur)	4,992
16	Dakota	CreU	S	*y*	1,120	1,140	*y*	A	Dakota (?)	
17	Morrison	Jur	S		6,664	6,704	40	D	Sundance (Jur)	6,898
	WYOMING									
1	Morrison	Jur	S	Por	4,570	4,600	30	A	Chugwater	5,460
2	Sundance	Jur	S	Por	2,100	2,175	40	A	Chugwater	4,083
3	Dakota	CreU	S	Por	3,951	3,957	6	A	Lakota	4,257
4	Frontier	CreU	S	Por	8,250	8,500	49	A		
5										
6	Frontier	CreU	S	Por	2,200	2,400	16	AF	Nugget	3,822
7	Dakota	CreU	S	Por	3,000	3,500	50	AF		
8										
9	Dakota	CreU	S	Por	2,950	3,100	20	AF	Chugwater	4,200
10	Sundance	Jur	S	Por	3,350	3,400	15	AF		
11	Lakota	CreU	S	Por	8,244	8,288	44	A	Sundance	8,920
12										
13	Shannon	CreU	S	Por	1,200	1,250	65	A	Madison	6,597
14	Wall Creek	CreU	S	Por	3,260	3,400	100	A		
15	Dakota	CreU	S	Por	4,600	4,700	15	A		
16										
17	Wall Creek	CreU	S	Por	2,300	2,800	150	A	Sundance	5,345
18	Lakota	CreL	S	Por	4,300	4,350	40	A		
19	Wall Creek	CreU	SH	Por	3,200	3,250	30	A	Big Horn lime	7,775
20	Embar-Tensleep	Per, Pen	LS	Cav Por	2,900	3,350	135	A	Madison	3,832
21										
22	Sundance	Jur	S	Por	1,015	1,120	10	AF	Amsden	2,867
23	Embar	Per	L	Cav	2,025	2,050	15	AF		
24	Shannon	CreU	S	Por	2,150	2,200	70	A	Niobrara	5,200
25	Shannon	CreU	S	Por	1,224	1,480	250	A	Sundance	6,791
26										
27	Frontier	CreU	S	Por	2,400	2,500	30	A	Amsden	6,700
28	Sundance	Jur	S	Por	4,205	4,209	4	A		
29	Embar-Tensleep	Per, Pen	LS	Cav Por	5,300	5,700	130	A		
30	Lakota	CreL	S	Por		8,019		A	Sundance	8,707
31	Embar-Tensleep	Per, Pen	LS	Cav Por	700	1,200	150	A	Tensleep	1,400
32	Leo Sand	Pen	S	Por	2,294	2,349	40	H	Minnelusa	2,505

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
33	Dutton Creek, *Carbon*				249,508	13,970
34	Shannon	1926		800		
35	Muddy	1926	150			
36	East Allen Lake, *Carbon*	1936		410		
37	East Lance Creek, *Niobrara*	1918	400	150		
38	Eight Mile Lake, *Carbon*	1923		250		
39	Elk Basin, *Park*	1915			10,971,926	204,483
40	Frontier		580			
41	Dakota			1,200		
42	Enos Creek, *Hot Springs*	1923				
43	Ferris, *Carbon*	1918	200	200	467,263	0
44	Ferris (West), *Carbon*					0
45	Dakota			3,100		
46	Sundance			3,500		
47	Fourbear, *Park*	1928	500			
48	Frannie, *Park*	1928			3,219,077	534,563
49	Tensleep		500			
50	Madison		10			
51	Garland, *Big Horn-Park*	1930			2,873,062	851,820
52	Frontier		40	1,000		
53	Dakota			1,200		
54	Embar-Tensleep		160	1,650		
55	Madison		2,000	500		
56	Golden Eagle, *Hot Springs*	1919		120		
57	Gooseberry, *Park*	1936	500			
58	Grass Creek, *Hot Springs*	1914			27,809,454	814,989
59	Frontier		1,400			
60	Embar-Tensleep		2,000			
61	Greybull, *Big Horn*	1907	640	160	346,730	0
62	Hamilton, *Hot Springs*	1913	2,000		5,056,079	188,433
63	Hidden Dome, *Washaki*	1933	50	640	282,335	25,908
64	Iron Creek, *Natrona*	1922	80	80	14,050	4,003
65	La Barge, *Lincoln-Sublette*	1923	950		5,833,699	332,055
66	Lake Creek, *Hot Springs*	1925	100			
67	Lance Creek, *Niobrara*	1918			22,669,864	692,331
68	Dakota		1,000	3,500		
69	Sundance		1,700			
70	Minnelusa		15,000			
71	Lander (Hudson), *Fremont*	1914	340		2,033,738	86,451
72	Little Buffalo Basin, *Park*	1914		4,800		
73	Little Grass Creek, *Hot Springs*			300		
74	Little Pole Cat, *Park*	1918		500		
75	Lost Soldier, *Sweetwater*	1915			19,774,751	692,331
76	Frontier		160	0		
77	Dakota-Lakota		450	0		
78	Sundance		160	0		
79	Tensleep		160	0		
80	Mahoney Dome, *Carbon*	1930			135,408	108,986
81	Dakota		0	1,400		
82	Sundance		0	1,660		
83	Tensleep		250	0		
84	Maverick Springs, *Fremont*		1,400			
85	Medicine Bow, *Carbon*	1935	800	320	3,270,351	606,240
86	Midway, *Natrona*	1930	200	0	175,163	3,790
87	Mule Creek (East), *Nibrara*				1,195,097	2,624
88	Lakota		220	0		
89	Minnelusa		100	0		
90	Mule Creek (West), *Niobrara*					
91	Dakota-Lakota		170	0		
92	Minnelusa		400	0		

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		A.P.I. at 60°Fe., Weighted Average	Sulphur, Per Cent
33			8	0	0	0	3	5	0	3				33.6	
34											440	295			
35															
36	(Included with Allen Lake)		2	0	0	0	0	2			1,050	1,000			
37			3	0	0	0	1	1	0	1	*y*	*y*			
38	4,934.4	64.4	4	0	0	0	0	1	0	0	1,724	600			
39		1,609.8	158	0	0	0	142	7	0	142				43	
40															
41											925	498			
42			3	0	0	0	0	1	0	0	750	730			
43			25	0	0	0	25	0	0	8	1,020	*y*		36.3	
44			13	0	0	0	0	13	0	0					
45	8,040	0									1,000	168			
46	16,692	*y*									1,140	168			
47			1	0	0	0	1	0	0	1	0	0		Tensleep 15	
48			16	1	0	0	14	0	1	13				Light 27.7 Heavy 17.6	
49															
50															
51			79	4	0	0	16	9	2	15				22	
52											*x*	*x*			
53											745	145			
54											1,470	1,260			
55											1,600	1,260			
56			3	0	0	0					1,175	Exh.[4]			
57			3	0	0	0	1	0	0	1				22	
58			331	0	0	0	331	0	0	331				Light 43° Heavy 19 to 24.7°	
59															
60															
61			14	0	0	0	3	0	0	3	*x*	Exh[4]		44.3	
62			36	1	0	0	34	0	0	34				Embar 25.6 Tensleep 16.7	
63			30	0	0	0	15	6	0	15	725	Exh		40	
64			5	0	0	0	1	0	0	1	200	Exh		32	
65			125	9	1	1	104	0	0	95				32	
66			3	0	0	0	1	0	1	0				26	
67			225	51	1	0	138	12	103					43.6	
68											910	*y*			
69											1,600	*y*			
70											2,000	*y*			
71			36	0	0	0	11		0	11				23.3	
72	19,168.5	1,797.5	13	3	0	0	0	11			690	393			
73			2	0	0	0	0	2			1,140	400			
74	1,026.1	113.1	1	0	0	0	0	1			1,375	1,090			
75			125	8	0	2	64	10	0	61				Light 32 Heavy 28.8	
76															
77															
78															
79															
80	57,726	540	17	2	0	0	4	9		2				32	
81											1,060	150			
82											1,170	168			
83															
84			32	0	0	0	32	0	0	32					
85	4,938	*y*	14	0	1	0	10	2	10		1,900	1,700		56.9	
86			3	0	0	0	3	0		3				32.5	
87			38	0	0	0	38	0	0	38					
88															
89															
90			46	1	0	0	22	0	0	22				32	
91															
92															

[4] Exhausted.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
33										
34	Shannon	CreU	S	Por	1,600	1,700	40	A	Sundance	5,448
35	Muddy	CreU	S	Por	4,850	4,900	30	A		
36	Sundance	Jur	S	Por	2,000	2,088	48	A	Sundance	2,180
37	Dakota	CreU	S	Por	3,808	4,008	95	A	Madison	6,434
38	Dakota	CreU	S	Por	3,400	3,500	50	A	Chugwater	4,560
39										
40	Frontier	CreU	S	Por	1,000	1,200	40	AF	Morrison	3,223
41	Dakota	CreU	S	Por	2,400	2,500	55	AF		
42	Frontier	CreU	S	Por	2,600	2,850	40	A	Dakota	3,992
43	Mowry-Dakota	CreU	S	Por	1,600	1,650	25	A	Embar	4,600
44										
45	Dakota	CreU	S	Por	2,200	2,300	30	A	Tensleep	4,690
46	Sundance	Jur	S	Por	2,600	2,700	110	A		
47	Tensleep	Pen	S	Por	3,270	3,350	60	A	Tensleep	3,350
48										
49	Tensleep	Pen	S	Por	2,770	3,530	100	AF	Madison	
50	Madison	Mis	L	Cav	3,012	3,013	1	AF		
51										
52	Frontier	CreU	S	Por	700	900	35	AF	Cambrian	4,750
53	Dakota	CreU	S	Por	1,500	1,600	50	AF		
54	Embar-Tensleep	Per, Pen	LS	Cav Por	3,000	4,275	100	A		
55	Madison	Mis	L	Por Cav	3,600	4,726	300	A		
56	Mesaverde	CreU	S	Por	2,250	3,000	50	A	Cody	4,019
57	Embar-Tensleep	Per, Pen	LS	Cav Por	5,669	6,049	50	A	Tensleep	6,076
58										
59	Frontier	CreU	S	Por	800	1,200	250	A	Amsden	4,335
60	Embar-Tensleep	Per Pen	LS	Cav Por	3,600	4,000	200	A		
61	Greybull	CreU	S	Por	1,000	1,050	20	AF	Tensleep	2,950
62	Embar-Tensleep	Per Pen	LS	Cav Por	2,700	3,332	130	A	Tensleep	2,886
63	Frontier	CreU	S	Por	1,200	1,600	15	A	Greybull	2,785
64	Dakota	CreU	S	Por	650	820	25	A	Sundance	1,633
65	Wasatch	Eoc	S	Por	650	1,000	150	AF	Hilliard	6,200
66	Embar	Per	L	Cav	3,730	3,760	30	A	Tensleep	3,830
67										
68	Dakota	CreU	S	Por	2,820	3,665	65	A	Granite	6,434
69	Sundance	Jur	S	Por	3,500	4,100	65	A		
70	Leo	Pen	S	Por	4,900	5,630	60	A		
71	Embar-Tensleep	Per Pen	LS	Cav Por	1,300	2,750	185	A	Tensleep	2,190
72	Frontier	CreU	S	Por	1,200	1,500	100	A	Mowry	1,670
73	Frontier	CreU	S	Por	2,665	2,901		A	Frontier	2,901
74	Frontier	CreU	S	Por	3,900	4,100	15	A	Cloverly	5,660
75										
76	Frontier	CreU	S	Por	175	900	200	AF	Tensleep	4,087
77	Dakota-Lakota	Cre	S	Por	1,375	2,100	80	AF		
78	Sundance	Jur	S	Por	1,875	2,100	300	AF		
79	Tensleep	Pen	S	Por	3,900	4,097	50	AF		
80										
81	Dakota	CreU	S	Por	2,170	2,300	30	A	Tensleep	4,690
82	Sundance	Jur	S	Por	2,600	2,760	110	A		
83	Tensleep	Pen	S	Por	4,600	4,760	160	A		
84	Embar	Per	L	Cav	1,450	1,700	50	A	Tensleep	2,094
85	Sundance	Jur	S	Por	5,200	5,430	140	A	Chugwater	5,910
86	Frontier-Muddy	CreU	S	Por	5,200	5,250	60	A	Chugwater	6,689
87										
88	Lakota	CreL	S	Por	1,500	1,550	25	A	Minnelusa	3,185
89	Minnelusa	Pen	S	Por	3,170	3,180	10	A		
90										
91	Dakota-Lakota	Cre	S	Por	170	350	30	A	Madison	3,047
92	Minnelusa	Pen	H	Fis	2,800	2,830	10	A		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres: Oil	Area Proved, Acres: Gas[b]	Total Oil Production, Bbl.: To End of 1939	Total Oil Production, Bbl.: During 1939
93	Muskrat, *Fremont*					
94	Frontier		0	500		
95	Dakota					
96	North Casper Creek, *Natrona*		100	0		
97	North Garland (Danker), *Park*		0	800		
98	North Sunshine, *Park*		150	0		
99	Notches, *Natrona*	1923	400		167,114	0
100	Oil Springs, *Carbon*		0	160		
101	Oregon Basin, *Park*	1927			11,649,327	1,006,756
102	Dakota		0	1,300		
103	Embar-Tensleep		10,000	0		
104	Osage, *Weston*	1920	10,000	0	4,356,818	238,530
105	Pilot Butte, *Fremont*	1916			561,862	12,285
106	Niobrara		250	0		
107	Muddy		0	400		
108	Pitchfork, *Park*		300	0		
109	Plunkett, *Fremont*		45	0	11,900	100
110	Powder River, *Natrona*		0	150		
111	Quealy, *Albany*	1934	160	0	1,227,232	226,921
112	Rex Lake, *Albany*	1923	200	0	229,026	1,060
113	Rock Creek, *Carbon*	1918			18,893,548	1,018,969
114	Dakota		1,300	0		
115	Sundance		500	0		
116	Salt Creek, *Natrona*	1908			288,363,422	5,336,240
117	1st Wall Creek		4,350	0		
118	2d Wall Creek		21,450	0		
119	Lakota		2,030	0		
120	Sundance		660	0		
121	Tensleep		640	0		
122	Shannon, *Natrona*	1889	200	0	55,441	0
123	Sheep Creek, *Fremont*		200	0	0	0
124	Shoshone, *Park*	1929	540	0	23,596	10,063
125	Simpson Ridge, *Carbon*	1924	160	0	462,465	0
126	South Casper Creek, *Natrona* and Poison Spider, *Natrona*	1920	240	0	3,440,510	36,648
127	South Sunshine, *Park*		300	0		
128	Spindletop, *Natrona*	1928	80	0	18,315	0
129	Spring Creek, *Park*		2,000	0	0	0
130	Spring Valley, *Uinta*	1903	400	0	101,593	0
131	Teapot, *Natrona* (outside Naval Reserve)	1927	x		99,760	0
132	Wall Creek					
133	Shale					
134	Torchlight, *Big Horn*	1915	600	0	270,279	0
135	Warm Springs, *Hot Springs*	1917	160	0	341,530	45,093
136	Waugh Dome, *Hot Springs*	1934	100	0	210,069	0
137	Wertz, *Carbon*				1,265,126	784,025
138	Frontier		0	100		
139	Dakota		0	500		
140	Lakota		0	500		
141	Sundance		0	200		
142	Tensleep		250	0		

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Line Number	Field, *County*	Year of Discovery	Area Proved, Acres: Oil	Area Proved, Acres: Gas[b]	Total Oil Production, Bbl.: To End of 1939	Total Oil Production, Bbl.: During 1939
1	Border, *Toole*	1930	450		1,024,018	37,563
2	Bowdoin-Saco, *Phillips Valley*	1916		100,000		
3	Bowes, *Blaine*	1926		3,000		
4	Boxelder, *Hill*	1931		900		
	Cat Creek (Petroleum), *Garfield*	1920				
5	First sand		600		14,660,961	193,874
6	Second sand		240			

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operations[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
93	10,892	3,100	5	1	0	0	0	4	0	0	2,175	*y*			
94															
95															
96			2	0	0	0	2	0	0	2				23	
97	50	10	4	0	0	0	0	4			400	*y*			
98			2	0	0	0	1	0	0	1				16	
99			5	0	0	0	1	0	0	1				23	
100	77.5	77.5	2	0	0	0	0	2			1,200	1,200			
101	2,303	250	43	2	1		35	5						21.6	
102															
103															
104			496	12	14	5	386	0						41.6	
105			17	0	1	0	13	2		13	800	800		42	
106															
107															
108			1	0	0	0	1	0						18	
109			19	2	0	0	3	0	0	3				42	
110			7	0	0	0	0	0			530	525			
111			19	0	0	0	17	0	17					32.8	
112			4	0	0	0	3	0	0	3				35	
113			72	1	0	0	55	0	0	72					
114														35	
115														33	
116			1,998	0	0	1	0	0	0	1,998					
117														36	
118														36	
119														38	
120														35	
121														35	
122			18	0	0	0								24	
123			4	0	0	0	2			2					
124			3	0	0	0	1							21.1	
125			12	0	0	0	2			3				20.4	
126	16,892	Exh												Tensleep 15.3 Sundance 21	
127			1	0	0	1	1	0		1					
128			6	0	0	0	5	0		5				22	
129			3	0	0	0	1	1		1					
130			30	0	0	0	2	0		2				48.3	
131			2	0	0	0	2	0		2				35.2	
132															
133															
134			30	0	0	1	0	0						45.6	
135			46	0	0	0	19	0	0	19				21	
136			2	0	0	0	0	0						27.2	
137	62,665	420	16	4	0	0	7	7	0	7				58	
138											850	Exh			
139											1,940	440			
140											1,940	297			
141											1,520	1,200			
142															

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1			35	0	4		17	1		17				34	1.20
2	5,469	64.9						30			217	*y*			
3	6,475	628						8			290	*y*			
4	2,031	311					104	4		104	430	*y*			
5														49	0.22
6														49	0.48

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
93										
94	Frontier	CreU	S	Por	4,270	4,340	150	AF	Madison	8,112
95	Dakota	CreU	S	Por	5,306	5,320	60	AF		
96	Tensleep	Pen	S	Por	3,200	3,210	10	A	Tensleep	3,308
97	Frontier	CreU	S	Por	2,200	2,400	30	AF	Frontier	2,800
98	Tensleep	Pen	S	Por	3,475	3,700	60	A	Tensleep	3,712
99	Tensleep	Pen	S	Por	2,800	2,850	40	A	Tensleep	2,830
100	Sundance	Jur	S	Por	2,225	2,353	90	A	Tensleep	2,353
101										
102	Dakota	CreU	S	Por	1,500	1,550	45	AF		
103	Embar-Tensleep	Per, Pen	LS	Cav Por	3,500	3,900	150	AF	Madison	4,160
104	Newcastle	CreU	S	Por	220	2,154	10	ML	Minnelusa	2,235
105										
106	Niobrara	CreU	H	Fis	800	1,000	*x*	A		
107	Muddy	CreU	S	Por	3,350	3,370	18	A	Sundance	4,630
108	Tensleep	Pen	S	Por	3,750	3,950	40	A	Tensleep	3,903
109	Mowry	CreU	H	Fis	250	500	*x*	N	Embar	2,500
110	Frontier	CreU	S	Por	1,315	1,350	35	A	Chugwater	3,460
111	Muddy-Dakota	CreU	S	Por	3,260	3,320	60	A	Sundance	4,207
112	Dakota	CreU	S	Por	3,800	3,900	50	A	Lakota	3,930
113										
114	Dakota	CreU	S	Por	2,600	3,300	110	A	Embar	5,627
115	Sundance	Jur	S	Por	3,150	3,250	100	A		
116										
117	1st Wall Creek	CreU	S	Por	1,000	1,100	110	AF	Granite	5,400
118	2d Wall Creek	CreU	S	Por	1,535	2,575	65	AF		
119	Lakota	CreL	S	Por	2,300	2,350	20	AF		
120	Sundance	Jur	S	Por	2,750	2,875	70	AF		
121	Tensleep	Pen	S	Por	3,970	3,980	190	AF		
122	Shannon	CreU	S	Por	800	900	75	MUP	Shannon	*y*
123	Embar	Per	L	Cav	2,035	2,100	75	A	Tensleep	3,905
124	Embar	Per	L	Cav	4,300	5,000	24	A	Tensleep	4,775
125	Quealy	CreU	S	Por	625	675	40	A	Steele sh.	6,931
126	Tensleep	Pen	S	Por	2,600	2,700	150	A	Tensleep	2,700
	Sundance	Jur	S	Por	1,400	1,425	35	A	Granite	4,119
127	Embar	Per	L	Cav	2,475	2,514	40	A	Embar	2,514
128	Sundance	Jur	S	Por	1,100	1,125	25	A	Tensleep	2,705
129	Embar-Tensleep-Amsden	Per, Pen	LS	Cav Por	3,660	4,255	270	A	Amsden	4,255
130	Aspen	CreU	H	Fis	400	900	*x*	MC	Bear River	2,065
131										
132	Wall Creek	CreU	S	Por	2,900	2,950	40	AF	Frontier	3,140
133	Shale	CreU	H	Fis	1,200	1,600	*x*	AF		
134	Mowry	CreU	SH	Por	400	600	50	A	Madison	4,165
135	Embar	Per	L	Cav	700	800	50	A	Tensleep	1,590
136	Embar	Per	L	Cav	3,775	3,807	35	A	Tensleep	4,246
137										
138	Frontier	CreU	S	Por	2,210	2,260	50	A		
139	Dakota	CreU	S	Por	3,500	3,550	50	A		
140	Lakota	CreL	S	Por	3,700	3,750	40	A	Tensleep	5,883
141	Sundance	Jur	S	Por	4,100	4,120	20	A		
142	Tensleep	Pen	S	Por	5,859	5,886	27	A		

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1	Vanalta	CreL	S, SH	14	2,470	2,500	15	MC	Madison (Miss)	2,645
2	Colorado	CreU	SH		750	720	50	D	Mississippian (?)	3,180
3	Eagle	CreU	S	15	975	1,045	100	D	Madison	4,700
4	Eagle	CreU	S	17	1,200	1,272	100	A	Eagle	1,276
5	First Cat Creek	CreU	S	15	1,200	1,245	50	AF		
6	Second Cat Creek	CreL	S	15	1,400	1,440	40	AF	Madison	1,964

Fort Collins Field, Larimer County.—Continental Oil Company's No. 1 Meyer, CWL. SE. SW. of sec. 19-8N-68W., in the Fort Collins field, completed on Oct. 7, 1939, was given an official initial production of 300 bbl. of oil and 50 bbl. of water a day pumping from Dakota sand at 4658 to 4683 ft. It was drilled to a total depth of 5206 ft. and after encountering water in Sundance sand at 5063 to 5202 ft. was plugged back to 4686 ft. and shot with 20 quarts of nitroglycerin between 4464 to 4480 ft. This is an old well deepened from 4492 ft. where it was completed in November of 1925 for 200 bbl. of oil a day in Muddy sand. This constitutes the discovery of oil in a new sand in an old field and will result in the ultimate recovery of a substantial amount of oil from a field that has produced upward of 2,000,000 bbl. of oil since its discovery in 1923.

Wilson Creek Field, Rio Blanco County.—The Wilson Creek field in Rio Blanco County, Colorado, was extended about one mile northwest late in the summer by the completion of No. 2 unit of The Texas Company and The California Company, NW.SE.SW. of sec. 27-3N-94W. The new well occupies about the same structural position as the discovery well

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
	Cedar Creek, *Dawson, Fallon and Wibaux*					
7	First sand	1913		110,000		
8	Second sand					
9	Madison lime	1936	80		17,588	Shut in
10	Cut Bank, *Glacier*	1932	38,000	55,000	16,922,483	3,535,956
	Dry Creek, *Carbon*	1930				
11	Frontier			1,760	1,510,998	306,483
12	Cloverly					
13	Elk Basin, *Carbon*	1916	140	40	987,853	13,997
14	Hardin, *Big Horn*	1928		2,000		
15	Kevin-Sunburst, *Toole*	1922	60,000		34,989,941	1,539,265
16	Lake Basin, *Stillwater*	1924	300	1,500	420,739	25,772
17	Pondera, *Pondera, Teton*	1927	1,600		5,362,144	283,984
18	Sweetgrass Hills, *Liberty, Toole*	1929	500	8,000	92,673	10,947
	UTAH					
1	Ashley Valley, *Uinta*	1926		240		
2	Cisco, *Grand*	1925		2,000		
3	Clay Basin, *Daggett*	1928		2,800		
4	Farnham, *Carbon*	1924		600		
5	San Juan, *San Juan*	1910	160		11,*xxx*	300
6	Virgin, *Washington*	1908	450		175,600	3,350

but it is west of the surface axis in an area of comparatively low dips. Further development of the field may now be expected to progress rapidly after the completion late next summer of No. 3 unit, NE.NE.NE. of sec. 27-3N-94W.

During 1939 the Wilson Creek field produced 129,506 bbl. of oil, most of which was taken from the discovery well and moved by truck from the field to The Texas Company's plant at Craig.

Divide Creek, Mesa County.—On Divide Creek, in Mesa County, Continental Oil Co. jointly with Amerada Petroleum Corporation and The California Company, hung up a record for deep drilling in Colorado when No. 1 Miller, SW.SW.NW. of sec. 36-8S-91W., was abandoned in Mancos shale at 10,815 ft. At the total depth, the well was only 1420 ft. below sea level, as the surface elevation is 9395 ft. The structure on which this test was drilled is a long anticlinal fold with about 1900 ft. of closure and embracing 15,000 acres of land within the closing contour. The length of the fold totals nearly 25 miles. Rocks of Wasatch (Tertiary) and

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939			Number of Wells						
				Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
7											220	125			
8								117			450	340			
9							2		Shut in					29.5	0.80
10							376	78		376	725	y		41	1.02
11	93,000	9,126					7	6	7		1,500	1,250		51	0.03
12															
13							22			22				43	0.14
14	653	71						30			137	80			
15	36,907	2,907					1,077	180	2	1,075	360	200		34	1.20
16							2			2	800	y		44.1	0.10
17							161			161				37	1.90
18	5,445						8	13		8	280	y		36	0.83

UTAH

Line Number	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil	Producing Gas	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Repressuring Operation	A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
1	21,644	471									580	195			
2	31,280	[5]									750				
3		41,321									2,250	y			
4		512[6]									750	300			
5														39	0.1
6														34	0.83

[5] Field abandoned and all wells plugged.
[6] Carbon dioxide gas.

Mesaverde (Cretaceous) form the surface, the former occupying the highest topographic points and the flanks, while the latter are exposed in a considerable area along the crest.

The well reached the base of the Mesaverde formation at 3980 ft. and was still in the underlying Mancos shale at the total depth. The only marker found in the well below the base of the Mesaverde at 3980 ft. was a sandstone at 4935 to 4945 ft., possibly an equivalent of the Morapos sand. The excessive thickness of Mancos shale found in the well is thought to be the result of thrust faulting.

El Dorado Structure, Boulder County.—The El Dorado structure was tested to the Hygiene sandstone member of the Pierre by Continental Oil Co. during the summer months and was abandoned late in October. This well, known as No. 1 Borra, on the SE.NE.SW. of sec. 5-1S-69W., had the top of the objective Hygiene series at 4395 ft. and was abandoned in that formation at a depth of 6381 ft. Elevation, 5375.51 ft. The structure as mapped by Continental geologists indicates a long northeast-southwest trending anticline formed in a graben between parallel faults.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
7	Judith River	CreU	S	15	1,460 830	900	70	A		
8	Eagle	CreU	SH	y	1,460	1,400	60	A		
9	Madison	Mis	L	y	6,750	6,800	50	A	Devonian	8,186
10	Cut Bank	Jur	S	14	2,800	2,835	30	MC	Madison	3,160
11	Frontier	CreU	S	18	4,400	4,450	50	AF		
12	Cloverly	CreL	S	y	5,500	5,525	25	AF	Tensleep	6,887
13	See Wyoming				See Wyoming					
14	Frontier	CreU	S	y	700	730	20	MF(?)	Tensleep	4,120
15	Ellis-Madison Contact.	Jur-Mis	L	y	1,450	1,470	10	[7]	Pre-Cambrian	4,710
16	Eagle, Frontier, Dakota	CreU, L	S	y	1,200	1,320	100	D	Madison	6,002
17	Madison	Mis	L	y	1,975	1,990		T	Madison	2,354
18	Upper Ellis	Jur	S	y	1,400	1,420		D	Madison	2,205
	UTAH									
1	Morrison	Jur	S	y	1,665	1,675	10	AF	Nugget-Jur	2,720
2	Dakota Morrison	CreU Jur	S	y	2,056	2,174	15	D	Kayenta-Jur	3,045
3	Dakota	CreU	S	18	5,700	5,800	40	D	Sundance-Jur	6,790
4	Coconino	Per	S	y	3,093	3,114	21	AF	Kaibab-Per	3,235
5	Goodridge	Pen	S	y	194	200	6	S	Hermosa-Pen	3,663
6	Kaibab-Moenkopi Contact or Upper Kaibab	Tr	L	y	663	665	2	MC	Coconino-Supai-Per	2,195

[7] Dome with accumulation localized by change in character of stratum.

Rangely Field, Rio Blanco County.—Shale-oil production in the Rangely field was increased considerably in the past year by development along fracture zones. In general, the fracture zones have a northeast-southwest strike and dip to the northwest at an angle of 60° to 70°. Most of the development has been on the fracture zone discovered by the Raven Oil & Refining Co. in the early '20's, at which time drilling was confined to a depth of about 800 ft. In the development of this zone in the past two years, the successful wells, some of which have productions greater than 100 bbl. of oil a day, have been completed at depths exceeding 1000 ft. Other fracture zones have been tested and found productive, one in the S½ of sec. 32-2N-102W., one near the SE¼ of sec. 24-2N-103W., and another near the center of sec. 25-2N-103W. A number of wells drilled in sec. 2, 3 and 11, in 1N-102W., obtained small production but whether or not accumulation occurs in a fracture zone similar to the others mentioned has not been determined.

Several other fracture zones in the field are marked at the surface by outcrops of calcite that have not yet been tested but appear to offer excellent prospects for the development of additional production.

The principal operators in the field are the Equity Oil Co., Raven Oil & Refining Co., John Bockhold and L. E. Jones.

At present production in the field is approximately 400 bbl., of which about 300 bbl. is trucked to Salt Lake City. The field has a capacity of about 500 bbl. a day and the market outlet is restricted to the production mentioned above.

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The Cut Bank field and the area to the north of Cut Bank were the most active spots in Montana in 1939. The results of drilling operations added about half a section of productive area to the old field south of Cut Bank and north of the Big Bend pool, and a section or more to the North Cut Bank field. Recovery of production in 1939 is shown in Fig. 1.

North Cut Bank Field, Glacier County.—The discovery well of North Cut Bank was drilled in 1933 by Santa Rita Oil and Gas Co., jointly with P. T. Sweeney. It is known as No. 1 Jacobson, C.NW.NW. of sec. 23-37N-5W., and produced 62 bbl. of oil initially from Darling sand at 2625 to 2628 ft. Late in the summer of 1933, following the completion of No. 1 Jacobson, Yukon Oil Co. drilled and abandoned its No. 1 Marie Krueger, C.SW.SW. of sec. 14-37N-5W., after encountering sulphur water in Madison lime at 2772 to 2775 ft. The Yukon well is a north offset to the discovery well. The upper part of the Darling sand at 2598 to 2668 ft. was dry. It contained slight oil saturation at 2623 ft., followed by water in the base. In later years the name of the Darling sand was changed to Cut Bank.

In the years that followed the completion of the discovery well and the offsetting dry hole, there was little activity until 1937, when A. B. Cobb started his No. 1 State, C.NE.NE. of sec. 30-37N-4W. He discovered gas in the upper bench of the Moulton sand at 2572 to 2585 ft. Late in 1938, the Cobb-State well was deepened to the second bench of the Moulton at 2597 to 2605 ft., where it gauged 40,000,000 cu. ft. of gas. In that same year Yukon Oil Co. completed its No. 1 Lundgren for 100 bbl. of oil a day from Moulton sand at 2562 to 2566 ft. This well is in the SE.SE.SW. of sec. 23-37N-5W., a little less than a mile south of the discovery well. Early in 1939, Nadeau Brothers' No. 1 Government, NW.SW.NW. of sec. 25-37N-5W., tested the Moulton, Sunburst and Cut Bank sands and was abandoned at 2805 ft. This well found the Moulton sand dry at 2652 to 2680 ft., and developed a showing of oil in Sunburst sand at 2735 to 2752 ft., followed by water at 2763 to 2768 ft. The Cut Bank sand was dry from 2775 to 2800 ft. but contained sulphur water at 2800 to 2805 ft., where the hole filled up 1400 ft. This well and Yukon Oil Company's No. 2 Lundgren, C.NE.NW. of sec. 26-37N-5W., mark the southern limits of the field. No. 2 Lundgren failed to produce although it is a south offset to No. 1 Lundgren, a producing oil well. The Moulton sand at 2500 to 2579 ft. had a showing of about 150,000 cu. ft. of gas with a spray of oil from 2572 to 2579 ft. It encountered a bailer of water an hour in Sunburst sand at 2632 to 2655 ft. The upper part of the Cut Bank sand at 2675 to 2708 ft. was dry, but had a small showing of oil from 2700 to 2708 ft. The lower part of the Cut Bank sand at 2708 to 2730 ft. contained water and at the total depth 2735 ft. the hole had filled up 2265 feet.

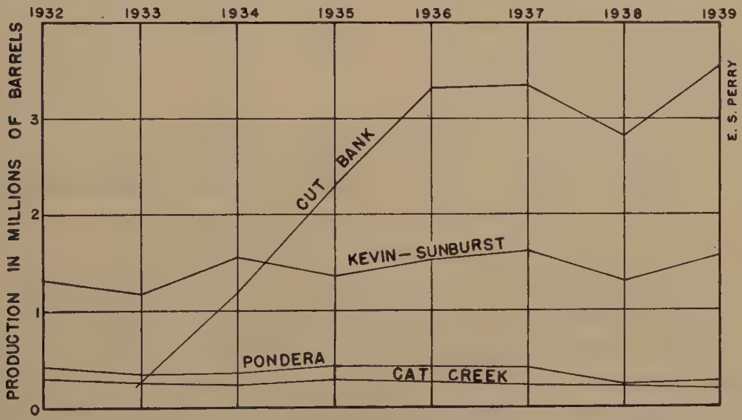

FIG. 1.—DECLINE OF PRODUCTION IN MONTANA'S MAIN OIL FIELDS IN 1938 AND RECOVERY IN 1939.

Chandler and Newell's No. 1 Hintrager, C.NE.NW. of sec. 24, was the second large Moulton-sand gas well completed in the field. It logged

Moulton sand at 2550 to 2596 ft. and gauged initially 43,000,000 cu. ft. The southwest offset to No. 1 Hintrager, Nadeau Brothers' No. 2 Government, C.SW.NW. of sec. 24, developed an estimated flow of 2,000,000 to 4,000,000 cu. ft. of gas in Moulton sand but was completed in Sunburst sand at 2658 to 2696 ft. for 45 bbl. of oil a day. The west offset to No. 1 Hintrager, the Huber-Montana Company's No. 3 Government, on the C.NW.NW. of sec. 24, had a good showing of oil on a drill-stem test in Moulton sand at 2574 to 2578 ft., but was drilled on down and completed for 76 bbl. of oil in 17 hr., flowing through the casing from Sunburst sand at 2662 to 2704 feet.

This concern's No. 2 Hintrager, C.NW.SW. of sec. 24-37N-5W., had the top of the Moulton sand at 2578 ft. and the base at 2628 ft. It developed an open flow of 2,500,000 cu. ft. of gas in the Moulton between 2594 and 2628 ft. and 60 bbl. of oil in Sunburst sand at 2692 to 2731 ft., where it was completed.

The freakish nature of the North Cut Bank area was further demonstrated by A. B. Cobb's No. 1 Vargo, C. SE. NE. of sec. 19-37N-4W., which had only a small showing of oil in the Moulton sand at 2600 to 2625 ft. and water in the Cut Bank at 2727 to 2753 ft., but after plugging back to the Sunburst sand at 2670 to 2680 ft., gauged 6,500,000 cu. ft. of gas.

A little over a mile north of the (1933) discovery well, Huber-Montana Company abandoned its No. 1 Krueger, CWL. SW. SE. of sec. 11-37N-5W., at 2802 ft. after encountering 1800 ft. of sulphur water in Madison lime at 2775 ft. A. B. Cobb's No. 1 Vasboe, C. NW. SW. of sec. 27-37N-5W., 1½ mile southwest of the discovery well, developed an open flow of 310,000 cu. ft. of gas in Sunburst sand at 2655 to 2679 ft. with light oil saturation at 2666 to 2672 ft. The Cut Bank sands at 2679 to 2700 ft., both the upper and lower bench, carried water, which filled the hole 300 ft. in 16 hours.

Cut Bank Field, Glacier County.—Drilling operations in the Cut Bank field proper were of routine nature all through 1939 and a large number of inside locations were drilled. The Big Bend pool was extended about a mile to the northeast, however, by operations of Glacier Production Co. This concern's No. 1 Stott, C. SE. NW. of sec. 34-33N-5W., tested 22 bbl. of oil and 139 bbl. of water in the first 24 hr. from Cut Bank sand at 3060 to 3100 ft. but after failure to cement off the water, the well was abandoned in Ellis shale at 3105 ft., and No. 1 Minnette, C. NE. NW. of sec. 34, the north offset to No. 1 Stott, was started. This well had a showing of oil in the lower part of the Sunburst sand at 2920 to 2930 ft. and in the upper Cut Bank at 2940 to 2950 ft., with main pay in the lower Cut Bank at 2950 to 2980 ft. where the hole filled up 1200 ft. with oil. On a swabbing test, the well made 87 bbl. of oil in the first 24-hr. period.

A Sunburst sand producer was completed ¾ mile north of the field proper. This well, Glacier Production Company's No. 1 Larson, CWL. NW. NE. of sec. 35-36N-6W., swabbed 150 bbl. of oil the first 12 hr. from Sunburst sand at 3022 to 3028 ft. The north offset, The Texas Company's No. 1 Ammerman, CWL. SW. SE. of sec. 26-35N-6W., found water in the Cut Bank sand at 3128 to 3148 ft. and was abandoned at 3158 ft. in Ellis shale. In this area, Glacier Production Co. completed Montana's largest gas well late in December. This well, No. 2 Rigney on the C. SE. SW. of sec. 35-36N-6W., gauged 80,000,000 cu. ft. of gas in sand at 2905 to 2959 ft., having previously gauged 31,000,000 cu. ft. in Moulton sand at 2910 to 2914 ft. before 8⅝-in. casing had been cemented at 2897 ft. and the hole deepened to the Cut Bank.

Kevin-Sunburst Field, Toole County.—All drilling operations in the Kevin-Sunburst field in 1939 were of a routine nature with only two minor extensions of the producing area. On the northeast side, Imperial Craig Oil Company's No. 1 Gauss, C. SW. NE. of sec. 18-35N-1W., completed for 35 bbl. of oil daily, after 500 gal. of acid, from the Ellis-Madison contact at 1626 ft., extended the field ¼ mile north. Operations by Coolidge and Coolidge on the west side of the field extended the producing area on that side ¼ mile north.

Seventy wells were completed in the Kevin-Sunburst field during the year, of which 52 were producing oil wells, one was a gas well and 17 were dry holes. One well was abandoned before reaching the sand. The average initial production of the new wells was not large and few wells of large capacity were completed.

A. E. Crumley's No. 16 Fryberger, on the SE. NE. SW. of sec. 24-35N-3W., was easily the best of the year's completions. Its initial capacity was 288 bbl. of oil a day with 500,000 cu. ft. of gas, flowing through tubing after treatment with 1000 gal. of acid.

Boris A. S. Aranow's No. 1 Ellingson, NE. SW. SW. of sec. 14-35N-3W., started at 200 bbl. of oil a day, but was pinched down to 65 bbl. by the operator to prevent water encroachment.

Big West Oil Company's No. 10 Dahlquist, CSL. SW. SE. of sec. 21-35N-3W., made 200 bbl. of oil initially on official gauge and has since given an excellent account of itself after having partly exhausted a heavy water flow. The capacity of this well has been variously estimated at from 800 to 1100 bbl. daily and probably would have exceeded the 200-bbl. gauge if it had been allowed to produce to capacity.

At the close of the year adverse weather conditions had slowed down operations to four drilling wells, all others were shut down temporarily and several of them will not attempt to resume until next spring.

Pendroy District, Teton County.—An occurrence of oil, which may lead to additional drilling, was reported from the Pendroy area, west of the Pondera oil field, when R. C. Tarrant's No. 1 Kirk-Hoeschen, C. NE.

SE. of sec. 34-27N-5W., flowed 10 bbl. of 31° A.P.I. gravity oil a day from Madison lime at 2295 to 2298 ft., top at 2283 ft., after three treatments with acid, a total of 3500 gal. Late in November, the operator decided it would be more profitable to produce the well for its gas and the hole was plugged back to a sand in the Colorado shale at 1560 to 1640 ft., where it was recompleted for 2,700,000 cu. ft. of gas a day.

Another occurrence of oil in Madison lime was reported from this area when No. 1 Kellog of Zodiac Oil Co. and Gulf State Oil Co. NE. NW. NE. of sec. 33-28N-5W., before abandonment pumped 1 bbl. of oil and 50 bbl. of water a day after treatment with 450 gal. of acid in Madison lime at 2835 to 2841 ft. This well was drilled on a geophysical high.

Sweetgrass District, Toole County.—A failure of more than ordinary interest was drilled in the Sweetgrass area late in the summer by Italo Petroleum Corporation on the Elmer Cornett farm in the C. SW. NW. of sec. 30-37N-3W. The location was on a broad structural nose, which turns northwestward toward the Border field. The Italo well was about 200 ft. higher structurally than wells in the near-by Border field. It developed an open flow of 800,000 cu. ft. of gas in the base of the Colorado at about 1500 ft., top at 285 ft., and had a showing of ½ bailer of oil an hour in Sunburst sand at 2305 ft. The top of the Madison lime was logged at 2675 ft. where the hole filled up 2000 ft. with sulphur water. After drilling into the lime 50 ft. the hole was abandoned at a total depth of 2725 feet.

Elk Basin Field, Carbon County.—The gas-producing area of the Elk Basin field of Wyoming was extended into Montana near the close of the year by the completion of a well by Minnelusa Oil Corporation and Henderson Producing Co., No. 1-H-11 on Elk 11, SE. SE. NW. of sec. 35-9N-23E., Carbon County, Montana, in Dakota sand at 2867 to 2877 ft. On drill-stem test, it showed for 8 to 10 bbl. of oil a day with 500,000 cu. ft. of gas but through tubing gauged 1,500,000 cu. ft. of gas with a spray of oil.

Elk Basin is one of the more important of the old Wyoming oil fields and has produced upward of 10,000,000 bbl. of oil since its discovery in 1915. It reached its economic limit in Frontier sands in 1933 but responded well to repressuring and will continue to produce from the Frontier for many years. The structure is believed to hold excellent possibilities in Permo-Pennsylvanian rocks, and a deep test is in prospect for 1940.

Wyoming

Horn Valley, Carbon County.—The Horn Valley fold was added to the list of Wyoming's gas fields in 1939, following the completion by Martin and Gaylord of their No. 1 Horn Brothers well on the CNL. NW.

SW. of sec. 22-22N-78 W. This well was started in September 1939 and completed before the first of January 1940, in Muddy sand at 750 to 805 ft. after plugging back from 1200 ft., for an initial production of 7,000,000 cu. ft. of gas under 325 lb. pressure. Additional encouraging showings of gas were reported in Dakota sand at 986 to 1000 ft., 1005 to 1036 ft. and the Lakota sand at 118 to 1153 ft. had a showing of oil and gas.

Wertz Dome Field, Carbon County.—The Wertz dome field in Carbon County, Wyoming, in which oil was discovered in upper Tensleep sand in 1936, became a major oil field in 1939 through the discovery of oil in the lower Tensleep. The original oil discovery in 1936 was made by Sinclair Wyoming Oil Co. in its No. 10-A Wertz, SW. SE. NW. of sec. 7-26N-89 W., and resulted in a 2000-bbl. well at 5863 to 5886 ft. Two additional Tensleep wells were completed by Sinclair Wyoming Oil Co. in 1937, No. 11-A for 410 bbl. a day and No. 12-B for 800 bbl. In August 1939, No. 11-A Wertz, SE. NW. NW. of sec. 7, was deepened from 5987 to 6238 ft., and discovered the pay in the lower Tensleep. In this pay, No. 11-A Wertz was credited with an initial production of 4622 bbl., flowing through the casing. The oil has a gravity of 35° A.P.I. Following the discovery, No. 10-A Wertz was deepened from 5896 to 6161 ft. and recompleted for 8350 bbl. of oil in 24 hr. After deepening from 5807 to 6086 ft., No. 12-B Wertz flowed 3607 bbl. of oil in 24 hr. through 2½-in. tubing. No. 13-A Wertz ,NE. NW. NW. of sec. 7, made 129 bbl. of oil an hour at 6065 ft. with a large increase at the total depth, 6230 feet.

Pinedale Structure, Sublette County.—An important test incomplete at the end of 1939 is The California Company's No. 1 Pinedale unit in C. SW. NE. of sec. 14-31N-109W., in Sublette County, western Wyoming. This well reached a depth of 10,000 ft. in October 1939 and set a new depth record for that state. The deepest well drilled in Wyoming previously was Amerada Petroleum Corporation's No. 1 Borie near Cheyenne, Wyoming, which reached a depth of 9385 ft., where it was abandoned in sandy red shale of the Jelm formation of Triassic age.

The Pinedale well started in Green River beds of Eocene age and at the total depth was in beds believed to belong in the Fort Union formation, also of Eocene age. The contact between the Green River and Wasatch has been tentatively placed at 4050 ft. and the top of the Fort Union at 6850 ft. This well had a showing of oil and gas in fine to coarse sand at 4238 to 4254 ft., which proved noncommercial and was cased off with 7 in. cemented at 8509 ft. The well is now standing shut in for the winter with 1500 ft. of perforated 4¾-in. liner set on bottom. Test of the well's volume will be made in the spring. The well is in the valley of the Newfork River, an important tributary of the Green River, on its south bank. The anticline, as seen from the rig, is clearly reflected in the low hills that parallel the river 2 miles north and in a low range of hills 3 miles southeast.

The Pinedale unit embraces approximately 71,000 acres of land and covers the anticlinal fold completely. The structure of the underlying beds is slightly reflected in generally flat-lying Tertiary beds suggesting a long, low, curving anticline. Before the well was drilled, The California Company mapped the area in detail by surface and geophysical methods.

Lance Creek Field, Niobrara County.—The Sundance sand area of the Lance Creek field was extended more than a mile east in March 1939, when The Ohio Oil Co. worked over its old Leo sand producer, No. 1 on Leo 7 in the NW. NW. SE. of sec. 35-36N-65W., and recompleted it in Sundance sand at 4304 to 4315 ft. for 194 bbl. of oil a day, producing through perforated casing. The Continental Oil Co., for the account of its subsidiary, Buck Creek Oil Co., went nearly ½ mile north and completed No. 5 on apex 4 in the NE. NE. NW. of sec. 35-36N-65W., for an initial production of 1005 bbl. of oil in basal Sundance sand at 4052 to 4095 ft. With this important change in the Sundance sand picture, the eastern limits of the field now remain to be determined.

Operations at Lance Creek in 1939 uncovered a pay in the Minnelusa formation deeper than the Leo and well above the Bell. At the outset of Minnelusa development at Lance Creek, three pay zones were recognized. These were named the Converse, Leo and Bell sands, representing upper, middle and lower Minnelusa, respectively. The new productive zone has been named the Joss, but some geologists believe this zone may be a part of the Leo.

The upper Minnelusa pay was discovered in The Ohio Oil Company's No. 5 on Converse Sheep. The middle Minnelusa in No. 5 on Leo 16—outside of the unit, but developed in Elizabeth Lamb 10, within the unit—and the lower Minnelusa was discovered in Buck Creek Oil Company's No. 10 Tom Bell Cattle. The so-called Joss sand was discovered in 1939 by Minnelusa Oil Corporation's No. 2 Joss, SE. NE. SW. of sec. 6-35N-65W., on the western edge of the field. This well is an old Sundance sand producer completed in February 1937, for an initial production of 100 bbl. of oil a day. In the deepening operations early in 1939, the Leo sand at 5154 to 5167 ft. made a very poor showing on drill-stem test, but deeper drilling resulted in the discovery of another pay at 5260 to 5307 ft. from which the well flowed 846 bbl. of oil over a 24-hr. period after acidizing with 2000 gal. It is not clear that this pay is a unit distinct from the Leo pay or that the original threefold division had any particular significance. An examination of the cuttings from the various wells in the field leaves the impression that accumulation is the result of porosity. The geological section would suggest that the Minnelusa formation, in addition to being a reservoir for the oil, is also the source.

Early in 1939, the production in the Joss zone was confined to wells on the west side of the field, but in October the Argo Oil Corporation's No. 7 Ford on the NW. SE. NW. of sec. 33-36N-65W., an outside well on the north side of the field, was completed at 5534 ft. for 2439 bbl. of oil initially. It had Leo sand at 5365 to 5407 ft. with the Joss at 5517 to 5534 ft., where it tested 30 bbl. of oil in 30 min. through the drill stem. The 7-in. production string was cemented on top of the Leo at 5365 ft. and the well is being produced from both zones. At the end of the year, Buck Creek Oil Company's No. 5-A Dielman, SE. NW. NW. of sec. 8-35N-65W., on the southeastern side of the field, was drilled to the Joss at 5585 ft. and found it saturated with oil. The hole was then plugged back to 5430 ft., where the well was completed in the Leo for an initial production of 1453 barrels.

There were 52 completions in the Lance Creek field in 1939, of which 31 were Leo sand oil wells, 4 were Joss sand oil wells, 15 Sundance sand wells, and one was a deep dry hole. Initial new production for the Minnelusa formation was 53,372 bbl. and for the Sundance sand 7342 barrels.

Wyoming Pipe Lines

The new oil pipe line of the Utah Oil Refining Co. from Ft. Laramie, Wyo., to Salt Lake City, Utah, was begun Aug. 11, 1939, and was the major pipe line construction in 1939 for the Rocky Mountain region. The line consists of 414 miles of 8-in. pipe from Ft. Laramie to Wasatch, Utah, and 24 miles of 6-in. pipe from Wasatch to Salt Lake City. A lateral of 31 miles of 4-in. pipe from Granger, Wyo. connects with the old Stanolind line from the La Barge field at Opal, Wyo. The Rock River field was connected into the main line by a 10-mile lateral of 4-in. pipe. Crude-oil deliveries from the Big Medicine Bow field are made through the lines of the Illinois Pipe Line Co. Since the main trunk line passes through Parco, Wyo., it will be possible to make deliveries from Lost Soldier Basin fields through the lines of Sinclair Wyoming Oil Co. The new line furnishes an additional outlet for 6000 bbl. a day of Lance Creek and Salt Creek oils. It connects at Ft. Laramie with the Stanolind pipe line from Salt Creek, to Freeman, Mo., and with the Rocky Mountain Pipe Line Co. and the Illinois Pipe Line Co. lines from Lance Creek. In addition to the pump station at Ft. Laramie, where oil enters the new line, pump stations have been built at Medicine Bow, Wamsutter and Granger, Wyoming.

The Socony-Vacuum Oil Co. completed a 20-mile oil line of 4-in. pipe from the Big Muddy field to its refinery in East Casper and began running oil from the field early in June.

The Ohio Oil Co. early last spring completed and put in operation a 6-in. gas pipe line from Oil Springs gas field, discovered in 1938, to a junction with its Allen Lake-Laramie line, a distance of 5.3 miles. Pipe for this line was strung late in the fall of 1938.

The Rocky Mountain Gas Co. in August 1939 completed a welded gas line, 12 miles long, which connects the Bunker Hill gas field to its gas-distribution system in the Rawlins district. The line consists of 11.8 miles of 6-in. and 0.2 mile of 4-in. pipe and connects into the main gas line from Mahoney dome to Rawlins and Parco. The new line furnished an outlet for two wells on the Bunker Hill dome, which were completed several years ago and have since been standing shut in.

The Illinois Pipe Line Company's Mule Creek line was abandoned this year and all pipe removed from Dakoming station on the Chicago, Burlington & Quincy Railroad to the company's pump station in the field. This leaves a few miles of 8-in. line in the system from the field to the pump station, but it is merely a part of the gathering system to the storage tanks at the pump station.

Montana Pipe Lines

The only pipe-line construction work in Montana in 1939 consisted of the replacement with 12-in. pipe of 8 miles of 8-in. pipe in the Billings Gas Company's gas line from the Elk Basin field in Wyoming to Billings, Montana.

A pipe line from the Cut Bank field in northern Montana to Spokane, Wash., is in prospect for 1940. The plans for the Inland Empire Refineries, Inc., call for 250 miles of 6-in. pipe. Such a line will traverse a mountainous country, but if completed will enable refineries in Washington to meet competition on the Pacific Coast.

Acknowledgments

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Oil and Gas Developments in Tennessee in 1939

By Kendall E. Born,* Junior Member A.I.M.E.

(New York Meeting, February 1940)

Production of crude oil in Tennessee during 1939 was slightly more than 51,000 bbl., an increase of about 10,000 bbl. over 1938. The production by counties and by fields is shown in Table 1.

Table 1.—*Oil Production in Tennessee for* 1939

Line No.	Field, *County*	Age, Years to End of 1939	Production in 1938, Bbl.	Production in 1939, Bbl.	Number of Wells Pumped	Producing Formation				Structure
						Name	Age	Character	Porosity	
1	Glenmary, *Scott*	23	4,674	4,332	4	Glenmary	MisU	L	Fis	AF
2	Boone Camp, *Morgan*	15	1,392	862	12	Boone Camp	MisL	LS	Fis	T
3	Seabolt, *Morgan*	11	1,564	1,401	3	Boone Camp	MisL	LS	Fis	T
4	Coon Hollow, *Morgan*	10	5,749	4,216	4	Boone Camp	MisL	LS	Fis	T
5	Beaty, *Fentress*	2½	1,*xxx*	1,2*xx*	1	Sunnybrook	Ord	L	Fis	D
6	Tinsleys Bottom, *Clay-Jackson*	15	100	1,*xxx*	1	Tinsleys Bottom	Ord	L	Fis	D
7	Jouett Creek, *Pickett*	13	1,100	Abandoned		Sunnybrook, Tinsleys Bottom	Ord	L	Fis	D
8	Pine Branch, *Clay*	2½	12,000	Temporarily abandoned		Tinsleys Bottom	Ord	L	Fis	D
9	Hargrove, *Clay*	3	1,250	1,*xxx*	4	Tinsleys Bottom	Ord	L	Fis	D
10	Goodpasture Bend, *Clay*	2½	7,300	3,1*xx*	1	Tinsleys Bottom	Ord	L	Fis	D
11	Irons Creek, *Clay*	12	640	Abandoned		Sunnybrook, Tinsleys Bottom	Ord	L	Fis	A
12	Arcott School, *Clay*	1½	4,*xxx*	1,*xxx*	1	Tinsleys Bottom	Ord	L	Fis	D
13	Turkey Creek, *Clay*	1½	400	Abandoned		Tinsleys Bottom	Ord	L	Fis	A
14	Celina, *Clay*	1	285	32,2*xx*	11	Tinsleys Bottom, Celina, Sunnybrook	Ord	L	Fis	D
15	Lock Branch, *Jackson*	12	270	2*xx*	6	Tinsleys Bottom	Ord	L	Fis	D
16	Scattered, *Clay, Pickett, Fentress.*		5*xx*	1,*xxx*	8	Sunnybrook, Tinsleys Bottom	Ord	L	Fis	A, D

The increased production has resulted from continued activity in the Upper Cumberland district, especially in Clay County, where approximately 37,000 bbl. were marketed off the lease. This figure includes a single well in the old Tinsleys Bottom pool on the Clay-Jackson County line, although the well is in Jackson County. The "Mississippi lime" produced 10,811 bbl. in Scott and Morgan Counties, a decrease of 2568 bbl. from the 1938 production. Production during the year from some half-dozen scattered wells in eastern Clay, Pickett, and Fentress Counties, on which there are no accurate figures, is estimated at 1000 barrels.

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There were 75 wells spudded in during 1939, of which 14 were drilling or only temporarily suspended on Dec. 31, 1939. Sixty-one wells were completed during the year; 14 were commercial producers, five encountered oil although they have not been put on pump, and two were gas wells which gauged more than 1,000,000 cu. ft. The total footage drilled on 1939 completions was 56,422 ft. Flush production during the year totaled 935 bbl. The more important wildcats are listed in Table 2; the distribution of oil and gas tests drilled during the year, according to physiographic divisions, is given in Table 3.

NATURAL GAS

The only natural gas marketed off the lease in Tennessee during the entire year was in Morgan County, where a small amount was furnished to the town of Sunbright and immediate vicinity. The gas occurs with the oil in the Boone Camp field and small amounts were put on the line from the near-by Coon Hollow and Seabolt pools.

Late in the year, natural gas was piped into Jamestown, the seat of Fentress County, from several wells about 6 miles south of the town. The producing horizons are in limestone of Trenton age at depths ranging from 450 to 850 ft. At the present writing, surveys have been completed to pipe natural gas into Lafayette, seat of Macon County, from several shallow wells approximately 5 miles east of the town. The producing horizons are in rocks of the Trenton group.

TABLE 2.—*Important Wildcat Tests Drilled in Tennessee during* 1939

Well Name	Number	County	Location	Drilled by	Total Depth, Ft.	Surface Formation	Deepest Formation Tested	Remarks
T. W. Roberts..	2	Clay	0.6 mi. NW. of Celina	Lain Oil & Gas Co.	1,128	Cannon (Ord)	Upper Canadian (Knox dolomite)	Commercial production in Knox at 1108–1115 ft.
Amos Jolly.....	1	Pickett	2 mi. SW. of Bloomington	Doctors Syndicate	1,770	Ft. Payne (Miss.)	Upper Canadian (Knox dolomite)	15 bbl. flush in Knox at 1612–1620 ft.
L. F. Choate....	1	Fentress	1 mi. SE. of Little Crab	Travis Smith et al.	Drlg.	Warsaw (Miss.)	Upper Canadian (Knox dolomite)	Testing good show of oil in Knox at 1860–1869 ft.
H. K. Jones....	1	Morgan	1 mi. W. of Sunbright	Tenn-Ohio Oil & Supply Co.	1,355	Pen	Middle Mississippian	1,155,000 cu. ft. of gas in Miss. at 1046 ft.
Allen Stevenson.	1	Giles	1 mi. NW. of Elkton	Indian Creek Oil Co.	878	Trenton (Ord)	Upper Canadian (Knox dolomite)	Tested upper Knox possibilities in Central Basin
A. E. Markham.	1	Lake	3.5 mi. SE. of Tiptonville	Henderson Oil Co.	3,990	Recent	Upper Cambrian	Oldest Paleozoics encountered in western Tennessee
Dyer Brothers..	1	Lauderdale	0.5 mi. N., 1.5 mi. E. of Halls	Raymond Gear	3,212	Recent	Lower Ordovician ?	Paleozoic top at 2501 ft. No encouraging shows in Cretaceous

DEVELOPMENTS

Cumberland Plateau.—There was one completion in the coal area of the state, a test that attempted to extend the lower Mississippian production in the Coon Hollow pool in Morgan County. This test, which was drilled to 1350 ft., found more than 1,000,000 cu. ft. of gas in the upper Mississippian at 1046 ft., and the well was completed as a commercial gasser. The Coon Hollow pay was dry, but a strong oil show was logged at 1194 ft., probably the Glenmary pay, which produces some 6 miles to the north. With the exception of developments in Scott and northern Morgan Counties, the Cumberland Plateau, especially the pre-Mississippian possibilities, remains essentially unexplored. In the light of present and past Ordovician production to the northwest in the Highland Rim area, the Cumberland Plateau is considered one of the most favorable areas for prospecting in Tennessee. Geologic work has been carried on by at least one of the major oil companies in the northern part of the Plateau. There was sporadic leasing in this area during the year.

TABLE 3.—*Physiographic Distribution of Wells Drilled in Tennessee during* 1939

Physiographic Division	County	Number of Wildcats	In Proven Fields	Number of Oil Wells	Number of Gas Wells
Cumberland Plateau	Morgan	1	0	0	1
Northeastern Highland Rim	Clay	19	16	12	0
	Jackson	3	0	0	0
	Pickett	3	0	1	0
	Overton	3	0	0	0
	Fentress	2	0	1	0
Northern Highland Rim	Macon	0	1	0	1
	Sumner	5	0	0	0
Central Basin	Coffee	2	0	0	0
	Giles	1	0	0	0
Mississippi Embayment	Dyer	2	0	0	0
	Lake	2	0	0	0
	Lauderdale	1	0	0	0

Northeastern Highland Rim.—As in previous years, the center of drilling activity was in the northeastern Highland Rim area, especially in Clay County. Of the 61 completions, 46 were drilled in this physiographic province. In response to this continued interest this Division issued a detailed report on Clay County during the year.[1]

The discovery of oil in a new horizon in the Trenton at depths of less than 350 ft. was largely responsible for renewed activity in Clay County. The most active area was in the immediate vicinity of Celina, where 23 wells were drilled, 10 of which were producers. Flush production from two wells in this area was more than 150 bbl. but the decline was rapid. Several of the wells were drilled deeper to the Black River-Stones River pays of this area, and three found production in these lower horizons. One test at Celina was completed as a 15-bbl. well in the upper part of the Knox dolomite group at the depth of 1115 ft. Although several tests had reported oil in these older beds, this completion marked the first commercial production in the Knox dolomite in several years.

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[1] K. E. Born and H. B. Burwell: Geology and Petroleum Resources of Clay County, Tennessee. Tenn. Div. Geol. (1939) **47**.

The year also witnessed the first successful acidizing of the Ordovician section in the Highland Rim region. The Matmon Farms, Inc., W. A. Marcum No. 1 acidized a strong show at 471 ft., and the well was completed as a 10-bbl. producer. The few previous attempts to acidize producing horizons or good shows in the northeastern Highland Rim had not been successful. Faulty technique and the lack of accurate drilling records contributed largely to these failures. Since most of the producing horizons in the Upper Cumberland district are rather pure limestones, 75 to over 90 per cent calcium carbonate, there is no apparent reason why intelligent acid treatment would not materially increase production in a large number of wells.

Middle Tennessee.—There were seven completions in Middle Tennessee during the year, all of which were completed as dry or near-dry holes. Continued attempts to extend the Devonian and Silurian production from Allen and Simpson Counties, Kentucky, were responsible for five completions in Sumner County, all of which were failures. Unsuccessful attempts were also made to find deeper production in northwest Coffee County, where a small amount of oil was found in the lower part of the Trenton at depths of less than 125 feet.

West Tennessee.—More than 200,000 acres of oil and gas leases were recorded during the year in the Mississippi embayment area of western Tennessee. Interest was attracted to this area by geophysical work carried on during 1938. This work continued during 1939, and was closely followed by an active leasing campaign. These activities were quickened appreciably by the discovery of oil in rocks of Upper Cretaceous age in Mississippi. Active leasing has been carried on in Tipton, Lauderdale, Dyer, Lake, and Obion Counties. Three wells in the northwestern part of the area were completed as dry holes into the upper part of the Paleozoic section. Sample studies of the sections encountered by these tests strongly suggest that Paleozoics are considerably older than has been previously considered.

ACKNOWLEDGMENTS

The writer acknowledges with thanks information supplied by Mr. Ralph Mong, of the Russell Producing Co., on the Cumberland Plateau region, and Mr. J. H. Overstreet, Celina, for data on the Upper Cumberland district. It is also a pleasure to acknowledge the cooperation of operators and drillers, who so kindly furnished information.

Development and Production in East and East Central Texas for 1939

By D. V. Carter,* Franklin M. Hackbusch,† and Dan C. Williams, Jr.†

(New York Meeting, February 1940)

During 1939 little of consequence happened in East and East Central Texas in the way of oil discoveries. At the end of the year, there were 47 oil and gas fields in the district. Twelve other fields, 11 oil and one gas, have been abandoned. The ranking fields in order of the number of completions for the year were East Texas, Talco, and Rodessa (Texas portion). There were 511 oil wells (distillate wells included), 32 gas wells, and 257 dry holes completed in the district.

Exploration, Discoveries and Extensions

During the year, 113 exploratory wells were drilled, the same number as in 1938; four oil fields and one gas-distillate field were discovered. Perhaps the most important discovery, which has been named Barron field, was that of M. Samuel et al., No. 1 Barron in Limestone County. The wells in this field are of the gas-distillate type. Other than the Talco and Sulphur Bluff fields, which produce oil from the Paluxy sand (Upper Trinity), this is the first field on the Corsicana-Mexia fault zone to obtain commercial production from deeper Trinity strata. This "pay" is the Petit lime of the Lower Glen Rose of the Trinity group.

The four oil discoveries were: Redland, Angelina County; Bazette, Henderson County; Rowe and Baker, Henderson County; and Marion County Shallow in Marion County. It is believed that the Bazette field, Navarro County, represents an extension of the Flag Lake field. For details concerning discoveries, extensions and important wildcat wells drilled during 1939 see Table 2.

Production and Proration

The district produced 175,053,729 bbl. of oil (distillate production included) which is a decrease of 4.0 per cent from the 182,369,484 bbl. (distillate production included) produced during 1938. The district's production for the year 1937 was 208,594,453 bbl. The East Texas

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TABLE 1.—*Oil and Gas Production in East and East Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Barron,[1] *Limestone*	1939	0	2*yy*	200*y*	200*y*
2	Bazette, *Navarro*	1939	1*yy*	0	13,002	13,002
3	Boggy Creek, *Cherokee*	1927	960	0	4,774,860	104,602
4	Bolivar, *Denton*	1937	600	200	6,271	2,349
5	Bosque, South, *McLennan*	1902	2,500	0	100,161	3,407
6	Buffalo,[2] *Leon*	1934	10	7,500	6,993 17,387	5,302 14,604
7	Carthage,[1] *Panola*	1936	0	1,9*yy*	25,546	6,733
8	Cayuga,[2] *Anderson, Henderson*	1934	4,000	9,000	586,520*R* 13,620,474	283,213*R* 3,356,608
9	Cayuga (Trinity), *Anderson, Henderson*	1938	*y*	*y*	4,677	4,677
10	Chapel Hill,[1] *Smith*	1938	*x*	*y*	89,949	75,307
11	Collinsville, *Grayson*	1938	100	0	19,382	7,318
12	Corsicana,[5] *Navarro*	1895	6,710	*y*	14,060,658	151,729
13	Currie,[6] *Navarro*	1921	475	*y*	6,828,359	38,545
14	East Texas, *Cherokee, Gregg, Rusk, Smith, Upshur*	1930	136,000	2,000	1,441,790,477	141,333,317
15	Flag Lake, *Henderson*	1937	1,280	0	289,918	151,959
16	Ginter, *Angelina*	1937	60	0	17,251	8,329
17	Grapeland,[2] *Houston*	1936	1,*yyy*	0	60,498*R* 52,369	44,113*R* 27,092
18	Groesbeck, *Limestone*	1924	0	60	*y*	*y*
19	Hemby (Elkhart), *Anderson*	1938	0	1*yy*	530*y*	180
20	Huntington, *Angelina*	1935	100	0	10,325	2,752
21	Joaquin,[1] *Shelby*	1936	0	6,*yyy*	39,068*R*	36,623*R*
22	Lone Star (Ponta), *Cherokee*	1938	100	*y*	16,502	10,263
23	Long Lake,[2] *Anderson*	1933	10,000	*y*	578,057*R* 2,555,048	244,510*R* 816,353
24	Lott, *Falls*	1937	3*yy*	0	21,614	7,314
25	Marion County (shallow)	1939	1*yy*	*x*	7,613	7,613
26	Mexia, *Limestone*	1920	3,920	*y*	96,669,173	609,361
27	Nacogdoches, *Nacogdoches*	1865	*y*	0	426,653*y*[8]	2,137[8]
28	Navarro Crossing,[2] *Houston*	1938	1,190	2,800	2,150 216,119	1,457 190,475
29	Nigger Creek, *Limestone*	1926	170	*y*	2,999,323	358
30	Opelika,[2] *Henderson*	1937	1,*yyy*	*y*	33,550 12,496	12,297 6,914
31	Panola (Bethany),[2] *Panola*	1921	60	23,000	3,120 97,457	3,120 6,339
32	Percilla, *Houston*	1937	1*yy*	*y*	24,307	5,272
33	Potter (Caddo), *Marion*	1905	980	0	7,654,722	28,327
34	Pottsboro, *Grayson*	1928	20	1,*yyy*	8,502*y*	1,331
35	Powell,[10] *Navarro*	1923	2,600	*y*	109,192,697	684,306
36	Red Lake,[1] *Freestone*	1934	0	3,*yyy*	2,463	313
37	Redland, *Angelina*	1939	10	0	60	60
38	Richland, *Navarro*	1924	440	*y*	6,631,725	5,810
39	Rodessa (Dees-Young), *Cass*	1935	5,010	3,250	22,620,186	3,889,738
40	Rodessa (Gloyd), *Marion*	1937	4,035	10,150	7,231,526	3,987,550
41	Rodessa (Gloyd), *Cass*	1936	1,885	10,150	7,119,294	1,788,965
42	Rodessa,[2] Total		10,930	23,550	719,700 36,971,006[11]	434,300 9,666,253[11]

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[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Distillate fields.

[2] Upper figure in column showing total oil production is distillate production. *R* indicates recycling plant.

[5] Includes Mildred, Angus-Edens, Hodge, Burk Rice, Oil Ridge and Old Powell shallow.

[6] Includes North Currie.

[8] Includes production from Chireno and Jennings fields.

[10] Includes shallow production discovered and produced since 1923 in the Powell Woodbine producing area.

[11] Production by horizons estimated.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	
				During 1939		End of 1939			Number of Wells					
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[5]	Producing Gas[6]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
1	y	y	1	1	0		0	1	0	0	y	y	61.0	
2	y	y	3	3	0		3	0	3	0	y	y	42.0	
3	y	y	33	0	0		18	0	0	18	650	y	38.5	
4	y	y	8	1	0		2	3	0	2	y	y	40.2	
5	0	0	54y	0	y		54	0	0	54	y	y	41.0	
6	3,257	2,538	9	2	0		1	8	1	0	2,185 2,289	1,801[3] 2,250[4]	49.0 24.7	
7	2,537	687	5	1	0		0	5	0	0	2,660	y	64.7	
8	61,561	15,942	296	10	0		257	39	236	21	1,750	1,583	63.0 28.6	
9	y	y	1	0	0		1	0	1	0	y	y	57.0	
10	2,022	1,059	1	0	0		0	1	0	0	2,900	y	62.8	
11	y	y	2	0	0		2	0	0	2	390	y	29.3	
12	y	y	2,937y	0	21		625	0	0	625	y	y	27.5	
13	y	y	54y	0	0		13	0	0	13	y	y	40.5	
14	511,836y[7]	50,173y[7]	26,725	382	265		26,114	6	19,307	6,807	1,620	1,066	39.0	
15	y	y	20	6	4		14	0	6	8	1,394	y	37.0	
16	0	0	3	1	0		3	0	0	3	y	y	20.9	
17	893	522	10	5	0		1	9	1	0	y	y	63.8 43.5	
18	72	38	5	0	0		0	5	0	0	875	y	Gas only	
19	137	35	1	0	0		0	1	0	0	2,200	y	59.2	
20	0	0	11	0	0		4	0	0	4	y	y	23.6	
21	1,552	1,434	7	3	0		0	7	0	0	2,550	y	37.0 48.0	
22	y	y	3	0	0		3	0	2	1	1,375	y	35.0	
23	36,106	9,260	138	26	0		86	52	86	0	2,440	2,289	63.0 41.0	
24	0	0	3	1	0		2	0	0	2	y	y	29.3	
25	y	y	8	8	0		8	0	1	7	y	y	40.0	
26	y	y	552y	0	38		232	0	0	232	y	y	35.0	
27	0	0	4y	0	17		20	0	0	20	y	y	23.0	
28	2,700	2,600	24	16	0		19	5	19	0	2,640	y	36.0	
29	y	y	75	0	0		1	0	0	1	y	y	40.0	
30	1,207	403	3	1	0		1	2	1	0	3,250 1,250y	y	58.7 38.9	
31	147,973	2,487	262y	0	15		4	134	0	4	y	y	60.0 28.0	
32	637	142	1	0	0		1	0	1	0	y	y	41.0	
33	y	y	60y	0	4		20	0	0	20	y	y	40.0	
34	350	0	15	0	0		2	0	0	2	300	y	38.8	
35	129,776y	171y	741	1	22		156	0	0	156	800y	y	37.8	
36	1,562	174	3	0	0		0	3	0	0	1,855	y	y	
37	0	0	2	2	0		2	0	0	2	y	y	23.0	
38	y	y	107	0	0		2	0	0	2	y	y	38.4	
39	74,511	13,433	278	0	0		268	5	179	89	2,700	942	42.1	
40	18,019	12,308	165	31	0		154	11	139	15	2,677	1,718	42.0	
41	23,934	11,133	72	0	0		67	0	41	26	2,700	739	42.0	
42	116,464	36,874	515	31	0		489	16	359	130				

[3] South Dome.

[4] North Dome.

[7] Estimate of gas only that produced with oil.

TABLE 1.—(*Continued*)

	Producing Formation								Deepest Zone Tested to End of 1939	
Line Number	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Lower Glen Rose	CreL	S	*y*	5,584	5,611	25	F	Travis Peak	6,051
2	Woodbine	CreU	S	*y*	2,992	3,008	15	F	Woodbine	3,008
3	Woodbine	CreU	S	25	3,632	3,666	34	Ds	Fredericksburg	4,648
4	Cisco	Pen	S, L	*y*	1,630	1,683	25	AF	Ellenberger	2,530
5	Basal Walnut	CreL	DL	*y*	450	475	3	AF	Trinity	1,800*y*
6	Woodbine	CreU	S	11	6,150 5,285	6,175 5,695	25 30	D	Washita CreL	6,300
7	Glen Rose	CreL	L	23	5,930	5,940	10	D	Travis Peak	6,019
8	Woodbine	CreU	S	25	3,680	3,758	78	AF	Trinity	9,085
9	Lower Glen Rose	CreL	L	*y*	7,600	7,612	10	AF	Trinity	7,612
10	Glen Rose	CreL	S	*y*	7,435	7,528	10	A	Glen Rose	7,528
11	Strawn	Pen	S	*y*	3,848	4,219	20	ML	Strawn	4,219
12	Nacatoch Corsicana (Wolfe City)	CreU	S	*y*	800	1,260	12–20	AF	Woodbine	3,570
13	Woodbine	CreU	SH	22	2,930	2,990	20	F	Woodbine	3,646
14	Woodbine	CreU	S	25	3,632	3,665	35	Shore line	Paluxy	5,020
15	Woodbine	CreU	S	20	3,085	3,105	10	AF	Travis Peak	6,518
16	Carrizo	Eoc	S	*y*	2,186	2,200	10	ML	Wilcox	2,265
17	Woodbine	CreU	S	25	5,975	6,025	40	A	Woodbine	6,033
18	Woodbine	CreU	SH	20	2,945	2,960	15	F	Woodbine	3,208
19	Woodbine	CreU	S	*y*	5,458	5,487	29		Woodbine	5,487
20	Queen City	Eoc	S	*y*	1,458	1,483	8	ML	Mt. Selman	1,490
21	Upper and Lower Glen Rose	CreL	L	*y*	4,097 5,070	4,107 5,138	10 30	D	Glen Rose	5,138
22	Woodbine	CreU	S	*y*	4,006	4,010	4	F	Woodbine	4,015
23	Woodbine	CreU	S	25	5,170	5,250	32	A	Trinity	9,966
24	Buda, U Washita	CreL	DL	*y*	1,250	1,275	10	F	Edwards	1,500
25	Tokio	CreU	L	*y*	2,336	2,346	10	A	Tokio	2,346
26	Woodbine	CreU	SH	25	3,000	3,085	50	F	CreL or older	8,847
27	Weches	Eoc	SH	*y*	80	100	*y*	ML	CreL	5,484
28	Woodbine	CreU	S	21–24	5,874	5,895	Gas 35 Oil 9	D	Woodbine	5,983
29	Woodbine	CreU	S	25	2,820	2,870	15	F	Woodbine	3,509
30	Glen Rose Lower Glen Rose Upper	CreL	LS	*y*	8,170 7,195	8,180 8,028	40 *y*	A	Travis Peak	9,320
31	Various[9]	CreU	S, L	*y*	1,100	5,700	40	A	Salt	11,303
32	Woodbine	CreU	S	*y*	5,665	5,670	5	A	Del Rio, CreL	6,634
33	Nacatoch-Tokio	CreU	S	20	1,025 2,300	1,040 2,366	*y* 15	A	Tokio, CreU	2,366
34	Trinity (Basal)	CreL	S	*y*	830	838	8	MU	Ordovician, or older	6,004
35	Woodbine	CreU	SH	25	2,925	3,000	40	F	Trinity	6,506
36	Woodbine	CreU	S	*y*	4,850	4,950	25	A	Woodbine	5,002
37	Wilcox	Eoc	S	*y*	1,021	1,032	8	ML	Wilcox	1,032
38	Woodbine	CreU	SH	25	2,975	3,040	20	F	Glen Rose	5,414
39	Dees Young, L. Glen Rose	CreL	L	17	5,794	6,040	25	F		
40	Gloyd, L. Glen Rose	CreL	L	15	6,044	6,094	20	F		
41	Gloyd, L. Glen Rose	CreL	S, L	16	5,914	6,000	20	F		
42									Salt CreL or older	11,484

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[9] Nacatoch 1100 ft., gas; Buckrang 1700, oil; Barlow 2300, gas; Adams 2650, gas; Tiller (Paluxy) 2300, gas; Werner 3600, gas; Jeter (Glen Rose) 5700, gas; Pettit, gas.

field accounted for 141,333,317 bbl., or 80.7 per cent of the district's total production for 1939. December daily average production in the district was 509,312 bbl. East and East Central Texas accounted for approximately 36.7 per cent of the state's total production for the year, which was 476,531,963 bbl. The importance of the annual production from this district is emphasized by the fact that for the year 1939 it represents 13.8 per cent of the annual production of the United States. The East Texas field alone accounted for 11.2 per cent of the nation's annual production.

The decrease in production in 1939 was largely due to proration restrictions and to the continuation of certain shutdown days each month. There were 115 shutdown days during the year in the East Texas field and 113 in the rest of the district. The entire district, except the Texas

TABLE 1.—(*Continued*)

Line Number	Field, *County*		Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
				Oil	Gas[b]	To End of 1939	During 1939
43	Rowe and Baker, *Henderson*		1939	20	0	4,984	4,984
44	Shelbyville, *Shelby*		1934	50	0	11,021	598
45	Sulphur Bluff, *Hopkins*		1936	730	0	4,939,772	1,538,860
46	Talco, *Titus, Franklin*		1936	8,450	0	30,286,658	9,583,786
47	Trinity (Kittrel), *Houston*		1934	280	0	1,478,156	168,296
48	Van (Deep), *Van Zandt*		1929	4,520	60	121,337,080	5,252,717
49	Van (Shallow) *Van Zandt*		1933	200	0	262,755	27,709
50	Total			4,720	0	121,599,835	5,280,426
51	Waskom, *Harrison*		1924	1,500	6,000	57,528	21,811
52	Willow Springs,[1] *Gregg*		1938	x	y	5,750	3,882
53	Wortham,[15] *Freestone*		1924	715	0	22,556,759	30,203
54	Total[2,16]					2,154,094 1,926,045,301	1,151,550 173,897,740[16]
	ABANDONED FIELDS	Year Discovery	Year Abd.				
55	Beulah (Lee-Tex), *Angelina*	1935	1935	10	0	750	0
56	Camp Hill, *Anderson*	1934	1937	200	0	286,414	0
57	Cedar Creek, *Limestone*	1927	1930	30	0	297,945	0
58	Chatfield, *Navarro*	1905	1910	0	150	0	0
59	Deberry, *Panola*	1931	1932	100	50	29,166	0
60	Kosse, *Limestone*	1922	1922	10	0	33,000	0
61	Mount Calm, *Hill*	1929	1939	x	x	x	0
62	Post Oak, *Falls*	1924	1939	1yy	0	190,205	0
63	Rusk, *Cherokee*	1934	1939	200	0	246,976	4,439
64	Satin, *Falls*	1932	1939	10	0	1,630	0
65	Tacoma, *Panola*	1933	1938	40	0	15,750	0
66	Witherspoon-McKie, *Navarro*	1915	1935	400	0	810,495	0
67	Total Abd. Fields					1,912,331	4,439
68	Grand total					2,154,094 1,927,957,632	1,151,550 173,902,179

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[15] Wortham Shallow discovered in 1912 included with Wortham.

[16] Oil production from Texas Railroad Commission records.

portion of the Rodessa field, was affected by the shutdown orders. In the latter part of August, a 15-day shutdown was imposed on the six Mid-Continent oil-producing states by each state's respective regulatory body. Certain wells were exempted in several states from the shutdown in order to prevent physical waste and to ensure a supply of domestic fuel.

Completions in the East Texas field declined from 1703 in 1938 to 382 in 1939, which may be attributed somewhat to changing the method of allocating well allowables. It is interesting that on Jan. 1, 1940, there were 26,114 producing oil wells, which is believed to represent the peak number of producing wells in the field.

The outstanding proration event was the changing of the allocation method in the East Texas field from a per well marginal plus potential

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	
				During 1939		End of 1939			Number of Wells					
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[e]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
43	*y*	*y*	2	2	0		2	0	0	2	*y*	*y*	31.7	
44	*y*	*y*	2	0	0		1	0	0	1	*y*	*y*	37.0	
45	*y*	*y*	74	0	0		74	0	12	62	1,900	*y*	22.4	
46	*y*	*y*	693	36	39		685	0	3	682	1,920	975	20.6	
47	443	50	20	4	0		16	0	1	15	870	*y*	24.0	
48	*y*	*y*	574	0	0		562[12]	3	338	224	1,230[13]	1,112[13] 624[14]	34.0	
49	*y*	*y*	31	0	1		30	0	0	30	*y*	*y*	31.0	
50	*y*	*y*	605	0	1		592	3	338	254	*y*	*y*		
51	98,923	3,089	226*y*	0	0		20	79	0	20	*y*	*y*	28.0	
52	514	313	2	0	0		0	2	0	0	2,870	*y*	56.9	
53	*y*	*y*	322	0	0		10	0	0	10			29.0 37.0	
54	1,120,522*y*	127,991*y*	34,648	543	426		29,560	381	20,378	9,182				
55	0		1		0						200*y*		24.0	
56	*y*		10*y*		0						1,950		40.6	
57	*y*		14		0						*x*		37.0	
58	4,750		15		0						250		Gas	
59	*x*		22		0						757		46.0	
60	0		1		0						*x*		32.0	
61	*x*		2		1						*x*		31.3	
62	0		25*y*		0						*x*		33.0	
63	0		5		2						*x*		42.0	
64	0		2		1						*x*		34.2	
65	0		3		0						*x*		46.0	
66	0		85		0						*x*		19.0	
67			185		4									
68	1,125,272*y*	127,991*y*	34,833*y*	543	430		29,560	381	20,378	9,182				

[12] Three wells producing from Sub-Clarksville.
[13] Brown sand.
[14] Bentonitic sand.

basis to an allocation formula that considers for each well: acre-feet of productive sand, reservoir pressure, and well potential in addition to a marginal allowable of 20 bbl. The ultimate outcome of the present method of allocation in this field is still undetermined early in 1940, as the question is on appeal to the United States Supreme Court.

RECYCLING PROJECTS AND SALT-WATER DISPOSAL

No additional recycling projects were completed during the year 1939 in any of the fields in this district, but early in 1940 two recycling plants were under construction—one in the Cayuga field, Anderson County, by Tide Water-Seaboard, and one in the Grapeland field, Houston County, by the Lone Star Gasoline Company.

Disposal of salt water by use of injection wells completed in the lower Woodbine sand in the East Texas field was adopted by more and

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
43	Woodbine	CreU	S	*y*	3,140	3,149	6	F	Woodbine	3,149
44	Blossom	CreL	S, L	*y*	2,690	2,700	10	ML	Georgetown	3,400
45	Paluxy	CreL	S	25	4,487	4,523	36	AF	Glen Rose	6,600
46	Paluxy	CreL	S	20	4,200	4,300	35	AF	Glen Rose	5,903
47	Carrizo	Eoc	S	*y*	1,995	2,013	10	Ds	Salt dome material	3,855
48	Woodbine	CreU	S	*y*	2,682	2,950	268	AF		
49	Nacatoch	CreU	S	*y*	1,200	1,220	20	AF		
50									Travis Peak	7,501
51	Nacatoch Blossom Glen Rose	CreU, L	S, SH, L	*y*	800	4,650	15–40	A	Glen Rose	4,980
52	Glen Rose	CreL	S, L	*y*	7,244	7,286	35		Lower Marine	10,284
53	Nacatoch Woodbine	CreU	S	25	1,361 2,990	1,371 3,050	6 35	F	Glen Rose	4,825
54										
55	Queen City	Eoc	S	*x*	2,045	2,053	5	Shallow	Carrizo	2,324
56	Sub-Clarksville (Eagle Ford); Woodbine	CreL	S, SH	*y*	5,054	5,059	5	AF	Lower Glen Rose	8,383
57	Woodbine	CreU	SH	25	2,885	2,940	10	F	Woodbine	3,310
58	Corsicana (Wolfe City)	CreU	S	*x*	880	1,020	13	A	Woodbine	3,057
59	Blossom	CreU	SH	*y*	1,990	2,087	*y*	ML	Blossom	2,125
60	Unknown	*x*	*x*	*x*	*x*	3,767	*x*	Crev.	Glen Rose	6,056
61	Austin	CreU	C	*x*	607	700	8	F	Travis Peak	3,398
62	Buda	CreL	L	*y*	1,025	1,046	10	F	Trinity	3,567
63	Woodbine	CreU	S	20	5,120	5,125	10	MU	Woodbine	5,302
64	Buda	CreL	L	20	1,000	1,160	20	AF	Glen Rose	1,409
65	Blossom	CreU	S	*y*	2,073	2,085	10	Shallow	Blossom	2,302
66	Nacatoch	CreU	S	14	825	875	19	AF	Woodbine	3,480
67										
68										

more operators during the past year. In March 1940 the Texas Railroad Commission promulgated an order whereby the allowable of oil wells converted into salt-water disposal wells would be credited to the remaining producing wells on the lease, provided an official Railroad Commission test of the wells made prior to their conversion indicated that they were capable of producing oil.

PRICE CHANGES FOR CRUDE OIL

Cayuga Field.—The Pan-American Petroleum and Transport Co. increased the posted price of crude oil from $0.68 to $0.78 per barrel effective Oct. 4, 1939.

East Texas Field.—The price of crude oil ($1.10 per barrel) remained steady until August, during which month a price reduction to $0.90 per barrel was made by some of the purchasing companies. This price reduction preceded the general shutdown throughout the Mid-Continent. About Sept. 1, 1939, some of the purchasing companies restored, on a gravity basis, a posted price of $1.10 per barrel for 39° A.P.I. gravity and above; this price was equivalent to restoring the price of East Texas oil which has an average gravity of 39° A.P.I. Early in October all of the purchasing companies posted a flat price of $1.10 per barrel.

TABLE 2.—*Summary of Drilling Operations in East and East Central Texas*

Discoveries, Extensions, and Important Wildcats Drilled during 1939

	Field	County	Drilled By	Well Number and Farm	Survey	Producing Formation
1	Redland	Angelina	K. L. McHenry	1, J. S. Russell	A. Flores	Wilcox
2	Barron	Limestone	M. Samuel et al.	1, C. Barron	W. McKinsey	L. Glen Rose
3	Marion Co. Shallow	Marion	J. D. Reynolds	1, Terry Est.	W. Coore	Tokio
4	Rowe and Baker	Henderson	Tyler & Smith	1, Rowe and Baker	J. Childers	Woodbine
5	Bazette	Navarro	Topaz Oil Co.	1, W. J. Trammel	A. C. Kyser	Woodbine
6	Navarro Crossing	Leon	Humble Oil & Ref.	1, Ed. F. Swift	H. Sublett	Woodbine
7	Cayuga (Trinity)	Anderson	Barnsdall	2, W. L. Tubbs		Trinity (GR)
8	Opelika	Henderson	Tidewater et al.	1, S. S. McGee	S. R. Acosta	Glen Rose
9		Smith	Texas Co.	1, A. Scritchfield	D. Page	
10		Hunt	Westmount Oil Co.	1, Clark	W. Williams	

Sulphur Bluff Field.—At the beginning of 1939 the American Liberty Pipe Line Co. posted a price of $0.55 per barrel. This price was increased to $0.65 on Oct. 2, 1939.

Talco Field.—The Humble Oil and Refining Co. increased the posted price of crude oil from $0.55 per barrel to $0.65 on Oct. 2, 1939.

CONSTRUCTION OF PIPE LINES

The Stanolind Pipe Line Co. completed 35 miles of 6-in. and 8-in. combination crude-oil pipe line from its Bullard station in the Cayuga field to its Bullock station, near Mexia, Limestone County.

The Navarro Crossing field, Houston County, was given a pipe line outlet by the completion of Humble Pipe Line Company's 26-mile 4-in. line, which connects with Humble's trunk line at Fairfield Station, Navarro County.

Sinclair-Prairie Pipe Line Co. completed 10 miles of 6-in. crude-oil pipe line from the Long Lake field, Anderson County, to its 12-in. main line between Red Lake and Palestine.

A 4-in. gasoline line 26 miles long, connecting the Cayuga and Long Lake fields, Anderson County, was completed by the Tide Water-Seaboard companies.

TABLE 2.—(*Continued*)

Discoveries, Extensions, and Important Wildcats Drilled during 1939

	Depth Completed, Ft.	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	1,021–1,032	1,032	Cook Mt.	Wilcox	3		Pump			95 per cent water, 23.0° gravity A.P.I.
2	5,584–5,611	6,051	Midway	Travis Peak	32	4.0	⅜	1,875	375	61.0° gravity A.P.I. water-white distillate
3	2,336–2,346	2,346	Wilcox	Tokio	20		Pump			40.0° gravity A.P.I.
4	3,140–3,149	3,149	Wilcox	Woodbine	70		Pump			88 per cent SW., 31.7° gravity A.P.I.
5	2,992–3,008	3,008	Alluvium	Woodbine	603		⅜	550	310	Extension to Flag Lake. 42.0° gravity A.P.I.
6	Perf. 5,841–5,842	5,906	Claiborne	Woodbine	106	1.5	7/32	1,825	1,700	Extension. 36.0° gravity A.P.I.
7	7,600–7,612	7,612	Wilcox	Trinity	40					57.0° gravity, new sand
8	8,170–8,180	8,216	Wilcox	Trinity	436	7.892	½	1,900	1,625	58.7° gravity A.P.I., distillate
9		8,100	Claiborne	Trinity	D. & A.					13 miles south of Tyler, Texas
10		5,314		Paleozoic	D. & A.					1 mile northwest of Celeste, Texas

	In Proved Fields	Wildcats
Number of wells drilling Dec. 31, 1939	36	17
Number of oil wells completed during 1939	507	4
Number of gas wells completed during 1939	31	1
Number of dry holes completed during 1939	149	108
Total wells completed during 1939	800	

TABLE 3.—*Production Statistics, East Texas Field*[a]

Date	Average Reservoir Pressure at −3300 Ft., Lb. per Sq. In.	Production, Bbl. (42 U. S. Gal.)	Number of Days Shut Down
Jan. 22	1,106.78	11,885,562	8
Feb. 17	1,106.35	10,374,983	8
Mar. 13	1,100.63	11,919,334	8
Apr. 14	1,100.79	12,930,841	5
May 12	1,087.53	12,940,313	6
June 10	1,086.04	11,385,120	8
July 11	1,083.22	11,869,691	8
Aug. 15	1,083.42	6,297,693	19
Sept. 10	1,108.89	12,032,782	11
Oct. 8	1,091.42	13,691,524	11
Nov. 8	1,070.88	12,989,799	11
Dec. 8	1,066.46	13,015,675	12
	Average 1,091.03	Total 141,333,317	Total 115

[a] Data from Texas Railroad Commission.

TABLE 4.—*Recovery Data on Older Woodbine Fields as of January* 1, 1940

Field	County	Cumulative Production, Bbl.	Proved Acres	Net Thickness, Ft.	Acre-Feet	Cumulative Production, Bbl. per Acre-Foot
Boggy Creek	Anderson	4,774,860	960	34	32,640	146
Cayuga	Anderson and Henderson	13,620,474	4,000	78	312,000	44
Currie	Navarro	6,828,359	475	20	9,500	719
East Texas	Cherokee, Gregg, Rusk, Smith, and Upshur	1,441,790,477	136,000	35	4,760,000	303
Mexia	Limestone	96,669,173	3,920	50	196,000	493
Nigger Creek	Limestone	2,999,323	170	15	2,550	1,176
Powell	Navarro	109,192,697	2,600	40	104,000	1,050
Richland	Navarro	6,631,725	440	20	8,800	754
Van (Deep)	Van Zandt	121,337,080	4,520	268	1,211,360	100
Wortham	Freestone	22,556,759	715	35	25,025	901
Cedar Creek[a]	Limestone	297,945	30	10	300	993
Rusk[a]	Cherokee	242,537	200	10	2,000	121

[a] Abandoned.

H. L. Hunt, Inc., secured a distillate and crude-oil outlet for the Chapel Hill field, Smith County, by completing 8 miles of 3-in line. The terminal for that line is Overton.

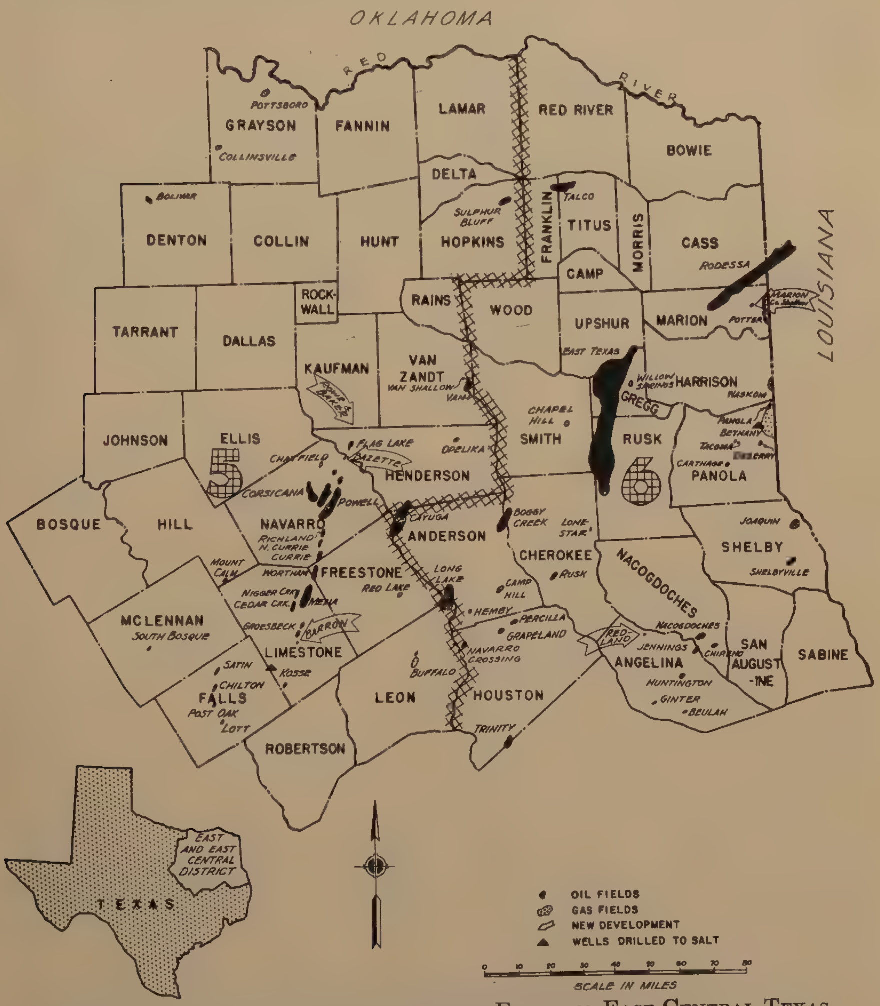

FIG. 1.—LOCATION OF OIL AND GAS FIELDS, EAST AND EAST CENTRAL TEXAS. (Texas Railroad Commission districts 5 and 6.)

The Magnolia Pipe Line Co. completed a 182-mile combination 4 and 5-in. butane line from its Kilgore station in the East Texas field to its Beaumont refinery in Jefferson County, on tide water. In addition, several gathering lines were laid to gasoline plants in the East Texas field to supply this line.

The new Barron field in Limestone County was given a gas outlet upon the completion of the Lone Star Gas Company's 10-mile, 6-in. extension line to its system near Groesbeck.

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Oil and Gas Production on the Texas Gulf Coast during 1939

By Perry Olcott*

(New York Meeting, February 1940)

The Texas Gulf Coast had a rather disappointing year in the type of oil fields found. Although 17 fields were found in the area during the year, as against 21 fields in 1938, no field of major proportion was discovered. Of these 17 fields, 11 were oil fields, 4 were gas and distillate fields, and 2 were gas fields.

The wildcat activity for the year resulted in about 400 dry holes, although probably 10 per cent of these were edge wells close to proved areas. During the year, 1455 oil and gas wells were completed as compared to 1637 wells in 1938, a decrease of 11 per cent.

Production for the Texas Gulf Coast area for the year was 100,253,937 bbl. as against 92,530,467 bbl. produced in 1938, an increase of 8 per cent. The daily average production was 274,668 bbl. for the 365 days in the year, although only 252 producing days were allowed by the Railroad Commission; that is, 69 per cent of the time as compared to 71 days shut in for 80 per cent of the time producing in 1938.

The total number of oil and distillate wells producing at the end of 1939 was 9495 as against 8451 at the end of 1938—an increase of 1044 wells, or 12 per cent. Of these wells, 6547 were flowing and 2948 pumping, or 69 per cent flowing. At the end of the previous year, 66 per cent of the wells were flowing.

New Fields

Angleton, Brazoria County.—The Angleton field was discovered by the completion of Glen McCarthy's No. 1 Carr in October for an initial production of 180 bbl. a day of 50° gravity oil through 11⁄64-in. choke with 3400 lb. on tubing. The field is 1½ miles east of the town of Anchor. The discovery undoubtedly can be credited to the reflection seismograph, since several companies worked the area from 1933 onward with this type of exploration. The principal block was taken by the Humble company in 1934. Two deep holes by Humble revealed the presence of structure, although both were dry. The Humble and Sun companies later contributed money and acreage toward the drilling of the discovery well. The production is from a sand in the Frio, about 1700 ft.

Summarized at meeting; manuscript received at the office of the Institute April 5, 1940.

* Humble Oil and Refining Co., Houston, Texas.

TABLE 1.—*Oil and Gas Production in Texas Gulf Coast*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939
1	Aldine, *Harris*	1939	20	200	16,063	16,063	None	None
2	Allen, *Brazoria*	1927	10	0	88,598	1,000	63	*x*
3	Amelia, *Jefferson*	1936	1,230	0	3,617,017	950,000	2,109	600[1]
4	Anahuac, *Chambers*	1935	6,745	0	12,728,206	2,600,000	8,640	1,500[1]
5	Angleton, *Brazoria*	1939	200	1,000	16,000	16,000	0	0
6	Aransas, *Aransas, San Patricio*	1936	4,000	0	5,937,625	3,084,000	11,848	5,000[1]
7	Ariola, *Hardin*	1932	100	0	1,926,971	80,395	712	62
8	Armour, *Matagorda*	1938	100	0	92,489	50,000	26	*x*
9	Bammel, *Harris*	1936	20	450	127,906	115,056	None	None
	Barber's Hill, *Chambers:*							
10	5,200 ft	1928	580	0	64,895,306	3,181,155	None	None
11	2,300 ft	1916	70	0	1,735,214		None	None
	Batson, *Hardin:*							
12	4,890–5,600 ft	1934	600	*y*	39,460,562	405,000	*x*	*x*
13	350–2,600 ft	1903				208,000	*x*	*x*
14	Bay City (Van Vleck), *Matagorda*	1934	1,200	0	2,708,777	860,025	*x*	0
15	Beeville, *Bee*	1935	20	0	1,000	1,000	*x*	*x*
16	Big Creek, *Ft. Bend*	1922	200	0	9,766,005	175,000	*x*	*x*
17	Big Hill, *Jefferson*	1923	10	0	13,853	Depleted dur. 1924	*x*	0
18	Big Hill, *Matagorda*	1904	15	0	210,906	Depleted dur. 1925	*y*	0
19	Blue Ridge, *Ft. Bend*	1919	350	0	11,111,204	281,658	0	0
20	Boling, *Wharton*	1925	304	0	6,721,661	555,000	500	*x*
21	Bonnieview, *Refugio*	1939	50	0	5,000	5,000	*x*	*x*
22	Brenham, *Washington, Austin*	1926	60	0	366,789	11,000	*x*	*x*
23	Brookshire, *Waller*	1934	50	0	22,314	1,000	12	*x*
24	Buckeye, *Matagorda*	1932	50	0	726,143	32,855	730	40[1]
25	Burnell (South), *Karnes*	1937	330	210	679,244	232,000	1,907	500[1]
26	Buttermilk Slough, *Matagorda*	1939	20	0	999	999	0	0
27	Caesar, *Bee*	1934	285	185	883,687	60,000	2,600	400[1]
28	Call, *Newton*	1937	100	0	15,376	0	5	0
29	Caplen, *Galveston*	1939	200	0	40,700	40,700	0	0
30	Cedar Point, *Chambers*	1938	410	0	391,249	278,000	300	150[1]
31	Cheek, *Jefferson*	1937	100	0	66,316	6,000	50	16[1]
32	Chriesman (Red Bank), *Burleson*	1938	50	0	9,531	5,000	0	0
33	Chocolate Bayou, *Brazoria*	1939	100	0	2,000	2,000	*x*	*x*
34	Citrus Grove, *Matagorda*	1939	0	1,800	0	0	Shut in	
35	Clam Lake, *Jefferson*	1937	100	0	86,596	52,000	65	30[1]
36	Clay Creek, *Washington*	1927	400	0	4,314,196	171,391	*x*	*x*
37	Clear Lake, *Harris*	1938	1,500	0	177,429	140,000	750	724[1]
38	Cleveland, *Liberty*	1933	400	0	1,179,762	110,000	702	60[1]
39	Clinton, *Harris*	1936	140	0	174,190	80,000	1,581	500[1]
40	Coletto Creek, *Victoria*	1934	500	0	1,024,802	126,000	1,000	150[1]
41	Cologne, *Victoria*	1939	0	640	0	0	226	226
42	Conroe, *Montgomery*	1931	20,000	0	107,574,432	9,315,000	68,045	3,000[1]
43	Cordele, *Jackson*	1938	320	0	803,539	690,000	*x*	*x*
	Cotton Lake:							
44	6,302 ft., *Chambers*	1936	1,000	*y*	576,383	124,193	*x*	*x*
45	Cotton Lake So. 6,502 ft., *Chambers*	1937			951,651	482,356		

[b] Footnotes to column heads and explanation of symbols are on page 239.
[1] Estimated.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1939	During 1939		End of 1939			Number of Wells		Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[e]	Flowing	Artificial Lift					
1	2	2	None	1	1	None	1	None	x	x		37	
2	5	0	x	0	1	0	0	1	200	0		34.3	
3	119	1	0	1	115	4	115	0	925	x		29.2	
4	320	41	0	x	302	10	299	3	3,260	x		34.4	
5	1	1	0	0	1	0	1	0	x	x		50	
6	286	144	0	x	264	2	240	24	2,200	x		42	
7	15	0	1	0	11	0	0	11	1,400	[2]		30–34	
8	5	0	0	2	3	0	3	0	1,000	x		34	
9	14	10	None	6	1	7	1	None	x	x		58	
10	398	6	16	3	158	0	28	130	296	x	30	27	None
11									x	x		x	
12	1,004	3	12	x	21	0	5	16	x	x		38.1	
13					185		0	185		[2]		y	
14	38	6	0	0	38	0	37	1	7,450–3,347 8,200–3,590 8,450–3,890	[2]	0	36.3	0.087
15	1	0	0	0	0	0	0	0	x	x			
16	83	0	0	0	23	0	0	23	400	[2]		28	
17	6	0	0	0	0	0	0	0	x	x		x	
18	3	0	0	0	0	0	0	0	x	x		x	
19	205	4	15	0	47	0	2	45	Variable		0	26.0	0
20	171	5	0	0	89	x	30	59	x	y		28.3	
21	2	1	0	0	1	1	1	0	x	x		55	
22	66	2	0	0	24	x	0	24	x	[2]		17	
23	1	0	0	0	1	0	0	1	100	[2]		24	
24	3	0	0	0	3	0	3	0	1,045	y		38	
25	43	0	0	0	33	6	21	12	1,425	x		47	
26	1	1	0	0	1	0	1	0	x	x	0	44.8	0.03
27	42	0	0	0	18	8	0	18	1,140 Gas 315	[2]		22	
28	1	0	1	0	0	0	0	0	1,475		0	39.6	
29	4	4	0	0	4	0	4	0	3,300		0	31–34	0.08
30	13	5	0	0	13	0	13	0	2,750	x		36.9	
31	3	0	0	3	0	0	0	0	2,950	x			
32	1	0	0	0	1	0	1	0	x	x	0	35.5	
33	1	1	0	0	1	0	1	0	x	x		51	
34	3	3	0	3	0	0	0	0	1,500	1,500	0		
35	9	6	0	0	7	x	7	0	2,500	x		22	
36	67	0	0	2	50	3	1	49	x	[2]	0	24.7	
37	33	29	0	0	23	1	22	1	650	x		26.4	
38	22	0	1	0	11	4	11	0	2,400	x		39	
39	16	5	0	0	8	2	6	2	4,800	x		x	
40	27	0	0	0	20	4	17	3	x	x			
41	3	3	0	1	0	2	0	0	1,100	1,100			
42	983	1	0	0	942	3	916	26	2,275	x		38	
43	48	33	0	0	42	6	42	0	80–340	x		22	
44	54	16	0	0	9	0	9	0	1,050	x		30.2	
45					36	0	36	0	1,050	x		30.2	

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[2] Pumping.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Eponides Yegua	Eoc	Sand	34	6,822	6,831	10	D	Cook Mtn.	7,665
2	Miocene	Mio	SH	Por		5,030	10	Ds	Mio	5,958
3	Frio	Olig	S	Por	6,745	6,780	15	D	Frio	8,261
4	Marginulina, Frio	Olig	S	Por	7,000	7,085	60	Df	Frio	8,749
5	Frio	Olig	Sand	Por	10,000	10,500	x	D	Frio	10,538
6	Marginulina, Frio	Olig	S	25–34	6,544	7,313	20	Ny	Frio	8,889
7	Miocene, Frio	Mio, Olig	S	Por	2,992	4,400	50±	Ds	Yegua	6,743
8	Marginulina, Frio	Olig	S	Por	6,620	6,624	4	N	Frio	7,531
9	Cockfield	Eoc	S	Por	6,185	6,200		Dsf	Wilcox	10,573
10	Miocene, Frio	Mio, Olig	S	30	3,450	6,690	80x	Ds	Jackson	8,184
11	Pliocene, Miocene	Pli, Mio	S	Por	800	2,300	42x	Ds		
12	Mid-Olig, Yegua	Olig, Eoc, Pli, Mio	S	Por	5,470	5,500	30	Ds	Cook Mtn.	6,502
13	Cap Rock, Lissie, Lagarto	Pre-Ter	L	Cav		1,250	y	Ds		
14	Frio	Olig	SH	27	7,000 to 8,500[3]	Various	Various	D	Vicksburg	11,467
15	Cockfield	Eoc	S	Por	4,825	4,832	7	F	Upper Saline Bayou	6,013
16	Pli, Mio, Mid-Olig, Frio	Mio-Olig	SH	Por		3,850	54	Ds	Frio	8,273
17	Pliocene, Miocene	Pli, Mio	S	Por		2,500	10	Ds	Marginulina	6,742
18	Cap Rock, Miocene	Pre-Ter, Mio	Lx	Cav, Por		862	x	Ds	x	3,807
19	Mio, Mid-Olig, Frio	Mio, Olig	S	30	3,000	3,600	60	Ds	Epon. Yegua	5,319
20	Cap Rock, Mid-Olig, Frio		L, SH	Cav, Por	377 2,500 4,817	500 4,089 4,859	60	Ds	Vicksburg	6,281
21	Frio	Olig	Sand	Por	4,200	5,250	15	T?	Frio	6,510
22	Oakville, Cockfield	Mio, Eoc	SH	Por	190 1,400	482 1,400	10x	Ds	Carrizo	3,930
23	Frio	Olig	S	Por	2,955	2,974	16	D	Hockleyensis	7,215
24	Frio	Olig	SH	Por	7,831	7,926	60	D	Frio	10,503
25	Cockfield (Pettus)	Eoc	S	Por	3,617	3,674	12	DF	Cockfield	3,936
26	Frio	Olig	Sand	20	7,850		7	Df	Frio-Olig	9,558
27	Cockfield (Pettus)	Eoc	S	Por	3,021	3,039	15	DF	Saline Bayou	4,230
28	Cockfield	Eoc	S	Por	6,908	6,918	10	NF	Yegua	7,380
29	Discorbis	Olig	S	25	7,350	7,500	40	Ds	Oligocene Discorbis	8,012
30	Frio	Olig	S	35	5,950	6,000	3–5	Ds	Lower Olig	8,505
31	Frio, Vicksburg	Olig, Eoc	S	Por	7,690	7,725–8,565	10	MF	Vicksburg	8,841
32	Edwards	CreL	LS	Por	6,167	6,172	5	F	Edwards	6,172
33	Frio	Olig	Sands	Por	9,800			D	Frio	10,385
34	Oakville	Mio	Sand	Por	3,550	4,175	85	A	Basal-Mio, Upper Olig	5,809
35	Miocene	Mio	S	Por	2,387	6,000	20	Ds	Frio	8,198
36	Claiborne, Wilcox	Eoc	SH		1,130	1,250	120	Ds	Wilcox	8,306
37	Frio	Olig	Sand	25	5,442	6,100	40	D	Frio	7,593
38	Cockfield, Yegua	Eoc	S	15	5,700	5,900	8	MF	Cook Mtn.	10,075
39	Miocene, Frio, Cockfield	Mio, Olig, Eoc	S	Por	3,200	8,100	50	D	Cockfield	8,783
40	Catahoula, Frio	Mio, Olig	S	Por	2,861	2,880	10	MF	Frio	5,368
41	Catahoula, Frio	Olig	S	Por	2,860	4,850	25+	NF	Vicksburg	5,168
42	U. Cockfield, Conroe	Eoc	S	27	5,000	5,150	14	D	Wilcox	9,040
43	Miocene, Catahoula	Mio	S	Por	2,654	2,753	15	Df	Vicksburg	5,177
44	Marginulina	Olig	S	Por	6,302	6,310	5	Df	Frio	7,019
45	Marginulina	Olig	S	Por	6,503	6,520	8	Ds		

[3] Eight sands.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939
46	Damon Mound, *Brazoria*	1915	10	0	9,536,217	97,000	x	x
47	Danbury, *Brazoria*	1929	200	20	284,027	155,000	267	80[1]
48	Diamond Half, *Goliad*	1936	240	0	351,039	66,979	Inc. with Refugio-New	
49	Dickinson, *Galveston*	1934	2,500	0	5,292,974	1,611,726	19,300	4,500[1]
50	Dinero, *Live Oak*	1935	50	20	71,421	6,945	37y	
51	Dirks, *Bee*	1934	865	0	5,051,338	599,000	x	x
52	East Placedo, *Victoria*	1937	300	0	235,869	132,000	100	48[1]
53	Edna, *Jackson*	1937	100	0	1,000x	1,000	x	x
54	Esperson, *Liberty*	1929	650	0	5,813,765	530,782	0	0
55	Eureka Heights, *Harris*	1935	1,054	60	1,311,332	1,056,201	6,990	4,296
56	Fairbanks, *Harris*	1938	3,160	1,300	3,430,070	2,615,898		1,530
57	Fannett, *Jefferson*	1926	105	0	2,558,436	150,000	1,234	30[1]
58	Fannin, *Goliad*	1939	x	x	0	0	x	x
59	Fort Merrill, *Live Oak*	1935	50	0	27,276	0	x	0
60	Francitas, *Jackson*	1938	1,000	0	72,231	70,000	x	x
61	Ganado, *Jackson*	1937	200		34,072	12,000	931x	74x
62	Garwood, *Colorado*	1933	40	0	6,434	4,000	x	x
63	Gillock, *Galveston*	1936	1,650	0	3,398,656	1,755,529	3,643	2,000[1]
64	Goose Creek, *Harris*	1912	910	0	77,319,931	625,000	x	x
65	Greens Lake, *Galveston*	1936	10	160	38,072	3,145		
66	Greta, *Refugio*	1933	5,414	1,050	24,409,724	1,964,000	17,250	1,500[1]
67	Hamman, *Matagorda*	1936	400	0	1,653,036	910,000	x	x
68	Hankamer, *Liberty*	1929	445	y	5,698,154	369,676	x	x
69	Hardin, *Liberty*	1935	3,000	20	4,217,602	2,180,000	6,074	2,000[1]
70	Hartzendorf, *Bee*	1935	20		Included with Pettus		x	x
71	Hastings, *Brazoria*	1934	5,500	0	22,132,141	6,334,000	8,419	2,100[1]
72	Hawkinsville, *Matagorda*	1936	50	0	3,616	0	x	x
73	Heyser, *Calhoun*	1936	4,000	0	8,202,673	3,474,000	5,475	2,800[1]
74	High Island, *Galveston*	1922	225	0	16,065,175	867,000	x	x
75	Hillje, *Wharton*	1939	100	y	2,500	2,500	28x	28x
76	Hitchcock, *Galveston*	1936	120	0	536,900	331,000	x	x
77	Hockley, *Harris*	1932	10	0	23,404	0	x	x
78	Holzmark, *Bee*	1935	80	20	34,669	9,000	72	20[1]
79	Hordes Creek, *Goliad*	1935	100	50	49,058	9,000	x	x
80	Hoskins Mound, *Brazoria*	1906	10	0	31,755	0	x	x
	Hull, *Liberty:*							
81	500–4,400 ft	1918	837	0	79,788,979	757,000	x	x
82	4,650–5,161 ft	1932			9,643,787	1,318,108		
	Humble, *Harris:*							
83	700 ft	1905	3,300	0	110,883,797	760,000	x	x
84	5,670 ft	1928			13,980,880	279,000		

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operations	Character of Oil	
	Completed to End of 1939	During 1939		End of 1939			Number of Wells		Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil^{e}	Producing Gas^{e}	Flowing	Artificial Lift					
46	128	2	0	0	34	*x*	1	33	*x*	^{z}		26	
47	14	1	0	0	12	*x*	2	10	500	*x*		23	
48					16		1	15	*x*	^{z}		47	
49	233	41	1	5	104	10	102	2	1,250	*x*		37.5	
50	4				2		1	1	1,600	*y*		43.0	
51	101	0	0	0	93	*x*	14	79	1,000	*x*		44	
52	14	3	0	0	12	*x*	12	0	1,080	*x*		38.5	
53	*x*	1	0	0	5	2	5	*x*	*x*	*x*		*y*	
54	73	8	3	1	52	2	15	37	100		PM	27.0	0.2
55	37	12	0	4	34	3	34	0	3,456 @ 7,600′	2,676	0	34.5	
56	271	142	0	0	258	13	257	1	3,000	2,875		37.8	0.0
57	30	3	0	0	20	1	1	19	540	^{z}		28	
58	1	1	0	0	0	1	0	0	*x*	*x*			
59	2	0	0	0	0	0	0	0	1,100	0			
60	7	5	0	0	7	0	7	0	2,450	*x*		48	
61	5	2	0	1	3	1	2	1	2,252	2,239	0	26.0	0.0
62	4	1	0	0	2	*x*	2	0	1,225	*x*		44	
63	Included with Dickinson				98		98	0	1,250	*x*		37.5	
64	902	1	2	0	83	*x*	0	83	*x*	^{z}		25.5	
65	3	1	1	0	1	1	0	1	1,300	^{z}	0	24.4	0.14
66	229	1	0	0	214	14	174	40	1,350	*x*		{23.2 {34.9	
67	38	6	0	0	22	*x*	17	5	800	*x*		37	
68	48	1	0	0	37	2	11	26	424	*x*		23.4	
69	146	38	0	0	140	3	131	9	900	*x*		36.3	
70	1	0	0	0	1	0	0	1	^{z}		0	45.0	
71	674	68	1		672	2	650*y*	22*y*	2,740*y*	2,710		31.5	*y*
72	1	0	0	0	0	0	0	0	200	0			
73	244	37	0	0	233	3	224	9	880	*x*		32.3	
74	132	3	3	5	58	0	19	39	*x*			32	
75	1	1	0	0	1	0	1	0	*y*	*y*	0	25.0	*x*
76	14	2	0	0	14	0	12	2	880	*x*		29	
77	3	0	0	0	0	0	0	0	40	0		32	
78	6	1	0	0	4	*x*	4	0	1,050	*x*		44.3	
79	3	0	0	0	2	*x*	2	0	1,550	*x*		47.6	
80	5	0	0	0	0	*x*	0	0	*x*	0		21.5	
81	769	0	20	*y*	102	0	0	102	*x*	*y*	0	30.0	*x*
82		1	7	*y*	74	0	5	69	*x*	*y*	0	38.0	*x*
83	1,768	4	6	0	234	*x*	0	234	*x*	*x*		26.5	
84			4	0	33	*x*	12	21				*y*	

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
46	Miocene, Mid-Oligocene, Vicksburg	Mio, Olig	SH	Por	1,406	3,800	43*x*	Ds	Vicksburg	8,112
47	Pliocene, Miocene	Pli, Mio	S	Por	1,955	1,970	20	Ds	L Olig	7,653
48	Cockfield (Pettus)	Eoc	S	Por	3,684	3,880	14	DF	*y*	*y*
49	Frio	Olig	S	Por	8,000	9,000	15	DF	Frio	9,463
50	Yegua	Eoc	S	Por	5,200	5,220	7	D	Cook Mtn.	5,913
51	Cockfield (Pettus)	Eoc	S	Por	3,819	3,990	16	DF	Yegua	4,776
52	Frio	Olig	SH	Por	6,370	6,382	15	Af	Frio	7,502
53	Catahoula, Frio	Mio, Olig	S	Por	2,646–3,890	2,830–5,350	10	D	Cockfield	7,180
54	Miocene, Heterostegina	Mio, Olig, Eoc	Sand	24		2,300 4,100 7,300	15 15 35	Ds	Weches	8,926
55	Cockfield	Eoc	Sand	27	7,690–8,080	7,720–8,100	25	A	Yegua	9,038
56	Yegua	Eoc	Sand	25–35	6,790	6,850	60	AF & AC	Cook Mtn.	7,940
57	Miocene, Mid-Olig, Frio	Mio, Olig	S	20	3,650	6,580	20	Ds	L Olig	7,949
58	Catahoula	Mio	S	Por	2,855	2,860	5	A	Frio	3,512
59	Yegua	Eoc	S	Por	4,643	4,706	5	D	Lower Saline Bayou	5,424
60	Frio	Olig	S	Por	7,380	7,950	15	A	Frio	9,030
61	Marginulina	Olig	S	Por	5,102	5,111	5	D	Frio	6,544
62	Frio, Lower-Olig, Cockfield	Olig, Eoc	S	Por	4,021	6,203	12	D	Yegua	6,777
63	Frio	Olig	S	Por	8,400	8,900	12	DF	Frio	9,463
64	Pliocene, Miocene, Mid-Oligocene, Frio, Vicksburg	Pli, Mio, Olig	SH	Por	1,000–5,875	4,600–5,894	40	D	McElroy	6,975
65	Miocene	Pli, Olig	Sand	20 25	3,630 6,808		12	Ds	Marginulina-Mid Olig	9,636
66	Catahoula, Heterostegina, Frio	Mio, Olig	Ss	20 33	2,000 3,470	2,100 3,500	20 18	A	Vicksburg	7,473
67	Frio	Olig	S	Por		8,182 9,183 9,370	10	Ds	Frio	11,465
68	Miocene, Frio	Mio, Olig	S	20*x*	2,650	7,700	*x*	Ds	Dibol Jackson	7,700
69	Yegua	Eoc	S	Por	7,500	7,690	20	D	Yegua	8,110
70	Pettus (Cockfield)	Eoc	SH	Por	3,642	3,651	9	A	Yegua	3,907
71	Marginulina, Frio	Olig	S	30	5,800	6,080	135	D	Vicksburg	8,792
72	Miocene	Mio	SH	Por	5,150	6,300	10	Ds	Olig	6,905
73	Frio	Olig	S	25	3,400	6,000	25	D	Frio	6,487
74	Pliocene, Miocene, Frio	Pli, Olig, Mio	Sand	Por	200	6,700	40	Ds	Mid-Olig	7,179
75	Marginulina	Olig	S	Por	5,220	5,230	10	D	Frio	6,524
76	Miocene	Mio	S	Por	5,118	5,134	16	D	Frio	10,460
77	Cap Rock, Frio	Pre-Ter, Olig	L SH	Cav Por	2,220	2,250	30	Ds	Cockfield	7,481
78	Cockfield (Pettus)	Eoc	S	Por	4,065	4,260	*y*	NF	Cockfield	4,458
79	Yegua	Eoc	SH	Por		4,575	10	MF	Cook Mtn.	6,004
80	*x*	*y*	SH	Por	600	623	23	Ds	Salt	1,150
81	Pliocene, Miocene, Middle Olig	Pli, Mio, Olig	S	Por	500	4,400	63	Ds	Cook Mtn.	6,845
82	Yegua	Eoc	SH	Por	4,650	5,806		Ds		
83	Cap Rock, Miocene, Oligocene	Pre, Ter, Mio, Olig	A	Cav, Por	600	5,400	40	Ds	Cook Mtn.	8,181
84	Mid-Olig Jackson, Cockfield, Yegua	Olig, Eoc	SH	Por	5,670	6,500	200			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939
85	Joes Lake, *Tyler*	1937	1,200		765,969	411,516	916	206
86	Katy, *Waller*	1935	200	2,500	75,000*x*	75,000	*x*	*x*
87	Keeran, *Victoria*	1932	350	40	1,103,192	249,000	613	100[1]
88	Kubela, *Wharton*	1936	300	0	349,713	235,059*y*	279	164*x*
89	La Belle, *Jefferson*	1937	650		289,860	145,603	0	0
90	Lamar, *Aransas*	1937	20	0	834	0	*x*	*x*
91	La Rosa, *Refugio*	1938	1,400	320	1,007,182	960,660	250	227
92	League City, *Galveston*	1938	600	0	386,959	380,000	*x*	*x*
93	Livingston, *Polk*	1933	1,698	0	5,525,014	560,000	2,761	260[1]
94	Lochridge, *Brazoria*	1936	750	0	1,706,968	843,000	1,006	400[1]
95	Lost Lake, *Chambers*	1929	80	0	972,106	34,562	*x*	*x*
96	Louise, *Wharton*	1933	1,614	0	2,649,881	436,060	*x*	*x*
97	Lovells Lake, *Jefferson*	1938	1,000	0	295,920	245,000	*x*	1,000[1]
98	Lucas, Mount, *Live Oak*	1923	500	4,000	241,878	17,412	50,598 ±	1,657
99	Magnet, *Wharton*	1936	450	80*y*	833,440	376,552*y*	527*x*	207*x*
	Manvel, *Brazoria*							
100	4016 ft	1931	692	0	7,951,507*y*	1,233,507*y*	3,667*x*	308*x*
101	5160 ft	1931	870	400	8,728,815*y*	1,364,127*y*	4,228*x*	546*x*
102	Markham, *Matagorda*	1908	220	0	7,722,608	597,000	*x*	*x*
103	Mathis, *Live Oak, San Patricio*	1924	0	100	*x*	0	*x*	*x*
104	Martha, *Liberty*	1939	160	0	27,299	27,299	0	0
105	Mauritz, *Jackson*	1935	100	0	212,599	46,700	0	0
106	McFaddin, *Victoria*	1932	650	0	1,194,822	740,000	1,732	500[1]
107	McMurray, *Bee*	1937	30	0	7,223	1,000	*x*	*x*
108	McNeil, *Live Oak*	1934	100	0	239,590	20,000	1,285	400[1]
109	Melon Creek, *Refugio*	1939	450	0	128,000	128,000	*x*	*x*
110	Mineral, *Bee*	1937	100	*y*	2,581*x*	*x*	*x*	*x*
111	Moss Bluff, *Liberty*	1930	10	0	179,235	0	*x*	*x*
112	Mountain View, *Live Oak*	1939	20	0	0	0	*x*	*x*
	Mykawa, *Harris:*							
113	Shallow	1929	270		3,828,162	47,884	*x*	*x*
114	Deep	1930				326,290		
115	Mission River, *Refugio*	1938	140		156,249	139,867	625	609
116	Nash, *Ft. Bend*	1926	120	0	1,665,226	0	*x*	*x*
117	Nome, *Jefferson*	1936	880	0	1,510,759	384,622		
118	Normanna, *Bee*	1930	70	10	78,600	12,000	*x*	*x*
	North Dayton, *Liberty*							
119	1,200 ft	1905	100	0	800,000	0	*x*	*x*
120	4,800 ft	1927			1,551,191	27,000		
121	North Markham, *Matagorda*	1938	80	0	40,155	26,913	150	125[1]
122	North Normanna, *Bee*	1938	10	0	955	0	*x*	*x*
123	Oakville, *Live Oak*	1936	150	290	119,623	89,000	2,730	1,200[1]
124	O'Connor-McFadden, *Refugio*	1931	200	200	521,127	39,000	24,672	2,500[1]
125	Old Ocean, *Brazoria*	1934	1,040	0	5,829,492	3,320,000	*x*	*x*
126	Orange, *Orange*	1913	400	0	32,622,418	176,992	*x*	*x*
127	Orchard, *Ft. Bend*	1926	200	50	3,460,346	173,000	*y*	*y*
128	Palacios, *Matagorda*	1937	80	0	105,999	25,000	343	100[1]
129	Pettus, *Bee*	1930	600	100	9,876,373	196,282	9,050	50[1]

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[a]	Character of Oil	
	Completed to End of 1939	During 1939		End of 1939			Number of Wells		Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
85	27	13	0	0	27	0	27	0	1,425	1,400[1]		45.8	
86	11	3	0	0	11	0	11	0	x	x		52	
87	28	9	0	0	19	1	18	1	1,450	x		36	
88	17	5	0	0	17	0	13	4	x	y	0	23.5	y
89	3	2	1	0	3	0	3	0	7,000	y	0	37.2	0.06
90	1	0	0	0	0	0	0	0	y	y		y	
91	72	59	0	0	68	2	67	1	850–1,775	800–1,700		39.0	
92	22	19	0	0	22	0	22	0	1,100–2,100	x		40.5	
93	97	0	0	2	86	x	31	55	700	y		37.5	
94	42	4	0	1	41	0	41	0	2,100y	x		28	
95	13	0	0	0	8	1	0	8	x	x	0	22.4	x
96	47	3	1	12	31	4	23	8	1,850	1,300	0	26.0	x
97	37	33	0	0	34	x	34	0	y	y		37.5	
98	41	0	0	6	3	15	0	3	874–1,400	[4]		36	
99	47	18	0	y	41	1	41	0	y	2,443	0	25.4	y
100	95y	0	1	y	87	0	18	69	x	1,558	0	24.0	y
101	87	2		0	83	4	74	9	x	2,448	0	26.0	y
102	149	6	0	0	30	x	5	25	x	[2]		26	
103	4	0	0	4	0	x	0	0	935	x		x	
104	4	4	0	0	4	0	4	0	3,509	x	0	41.0	x
105	4	2	1	0	4	0	3	1	2,467	2,446	0	31.0	0.11
106	60	28	0	0	48	4	48	0	1,185–1,725	x		21.2	
107	2	0	0	0	2	0	0	2	570	[2]		47	
108	7	0	0	0	5	x	4	1	1,150	x		44.3	
109	10	10	0	0	10	0	10	0	x	x		35.5	
110	12	0	x	x	x	x	x	x	100	x		45	
111	5	0	0	0	0	0	0	0	280	0		29.7	
112	1	1	0	0	0	1	0	0	x	x		x	
113	38	0	1	0	9	x	0	9	290	x		27.5	
114					20		20	0					
115	7	5	0	0	7	0	7	0	590–1,100	y	0	42.6	
116	24	0	0	0	0	0	0	0	800	0		19.9	
117	44	0	0	0	42	1	33	9	2,550	2,497	0	28.0	0.25
118	7	0	0	0	5	x	2	3	150	x		38.8	
119	62	0	0	0	0	x	0	0	x	x[2]		24	
120					10		0	10	400			36	
121	2	0	0	0	2	0	2	0	3,450	3,440	0	37.0	y
122	1	0	0	0	0	0	0	0	y	0		46.5	
123	18	10	0	0	14	4	7	7	1,300	x[2]		23	
124	10	0	0	0	4	6	1	3	365			22.6	
125	43	22	0	0	43	0	42	1	4,700	x[2]	0	52	
126	316	0	5		38	0	0	38	x			23.8	
127	34	2	0	3	17	0	4	13	375	x		38	
128	4	0	0	0	4	0	4	0	x	x[2]		53	
129	88	0	0	0	36	x	0	36	236			47	

[4] Jetting.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
85	Carrizo Wilcox	Eoc	S	Por	7,600	7,700	30[1]	DF	Wilcox	9,014
86	Upper Saline Bayou	Eoc	Sand	Por	7,400	7,500	100	Ds	Wilcox?	11,080
87	Frio	Olig	S	15	5,597	7,011	10	MF	Frio	7,850
88	Marginulina	Olig	S	Por	4,590	4,719	10[1]	N	Jackson	8,888
89	Marginulina	Olig	Sand	30	8,620	8,650	20[1]	Ds	Frio	10,147
90	Frio	Olig	S	Por		7,997	*y*	*y*	Frio	9,785
91	Frio	Olig	S	Por	5,382	6,385	20[1]±	Dfy	Frio	7,021
92	Discorbis, Frio	Olig	S	Por	8,695	10,960	20	D	Vicksburg	10,969
93	Cockfield	Eoc	S	Por	4,180	4,276	15	DF	Cockfield	5,596
94	Frio	Olig	S	20	6,342	6,365	23	AF	Vicksburg	8,698
95	Frio	Olig	S	Por	2,679–5,128	2,735–5,157	33[1]	Ds	Frio	7,471
96	Frio	Olig	S	Por	5,128–6,457	5,157–6,467	20	NF	Vicksburg	8,271
97	Frio	Olig	S	30	7,713–7,770	7,725–7,792	22	Ds	Frio	8,189
98	Catahoula, Frio, Yegua	Olig, Eoc	S SH	Por	1,750	5,300	28[1]	D	Cook Mtn.	6,789
99	Marginulina	Olig	S	Por	5,551	5,662	15[1]	D	Frio	6,518
100	Miocene	Mio	SH	Por	3,990	4,016	23[1]	D	Vicksburg	7,957
101	Marginulina	Olig	S	Por	5,000	5,500	26[1]	D	Vicksburg	7,957
102	Cap Rock, Pli, Mio, Mid-Mio, Olig	Pre-Ter, Pli, Mio, Olig	L SH Ss	Cav, Por	936	4,350	40*x*	Ds	L Olig	6,436
103	Catahoula	Mio	S	Por	2,375	2,385	10	ML	McElroy	5,526
104	Yegua	Eoc	S	30	8,100	8,130	15	AF	Yegua	9,113
105	Frio	Olig	S		5,640	5,650	8[1]	ML	Frio	7,408
106	Catahoula, Heterostegina Frio	Mio Olig	S	Por	2,440 4,400	2,470 5,300	24 10	AF	Frio	7,025
107	Yegua	Eoc	S	Por	4,267	4,284	8	NF	Yegua	4,379
108	Hockleyensis, Cockfield	Eoc	S	Por	4,434	4,992	10	D	Cook Mtn.	6,212
109	Frio	Olig	S	Por	5,856	5,876	20	A	Frio	5,876
110	Cockfield (Pettus)	Eoc	S	Por	3,545	3,650	8	NF	Cockfield	4,536
111	Cap Rock, Marginulina	Pre-Ter, Olig	SH	Cav, Por	800	5,800	33	Ds	Vicksburg	7,375
112	Jackson	Eoc	Sand	Por	2,135	2,148	10	F	Cockfield	3,000
113	Miocene, Heterostegina	Mio, Olig	SH	Por	4,100	4,300	*y*	D	Whitsett	7,355
114	Frio	Olig	SH	Por	4,400	4,593	*y*	D		
115	Frio	Olig	SH	Por	5,445[1]	7,150[1]	15[1]±	D	Vicksburg	9,225
116	Miocene, Mid-Oligocene	Mio, Olig	S SH	Por	3,700	5,677	60*y*	Ds	Vicksburg	6,800
117	Frio	Olig	S	Por	6,010	6,055[1]	9[1]	Ds	Vicksburg	8,768
118	Hockleyensis	Eoc	SH	Por	3,500	3,676[1]	17	D	Yegua	5,038
119	Pliocene, Miocene	Pli, Mio	Ss	Por	400	1,200	*y*	Ds	Yegua	6,077
120	Miocene, Frio, Vicksburg	Mio, Olig	SH	Por	4,075	5,188	32*x*	Ds		
121	Frio	Olig	S	30	7,730	7,930[1]	15[1]	AF	Frio	8,869
122	Pettus (Cockfield)	Eoc	SH	Por	4,221	4,226[1]	5[1]	MF	Cockfield	4,273
123	Cockfield (Pettus)	Eoc	S	Por	2,136	2,828[1]	8[1]	AF	Cook Mtn.	4,500
124	Catahoula, Cockfield (Pettus)	Mio, Eoc	S	Por	2,136	2,828	8	AF	Frio	6,860
125	Frio	Olig	S	Por	8,632	8,654 9,965 10,650	100	D	Vicksburg	11,130
126	Pli-Mio, Mid-Olig, Frio	Pli, Mio, Olig	S	Por	2,500	5,300[1]	30*x*	D	Frio	7,550
127	Miocene, Frio, Cockfield, Saline Bayou	Mio, Olig, Eoc	S	20	1,266	7,900	30	Ds	Crockett	10,085
128	Frio	Olig	S	Por	7,830	7,880	10	D	Frio	11,327
129	Cockfield (Pettus)	Eoc	S	Por	3,860	3,900	19	DF	Queen City	7,569

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939
130	New Pettus, *Bee, Goliad, Karnes*	1930	950	50	2,972,903	244,730	1,121	30[1]
131	Picketts Ridge, *Wharton*	1935	700	1,000	2,020,657	347,572*y*	5,317*y*	1,348*y*
132	Pierce Junction, *Harris*	1921	340	0	32,897,783	895,000	*x*	*x*
133	Placedo, *Victoria*	1935	2,950	50	9,488,862	2,175,000	3,957	300[1]
134	Pledger, *Brazoria*	1932	20	1,100	17,068*x*	*x*	10,051	2,000
135	Plummer, *Bee*	1936	100	20	201,873	70,000	414	150[1]
136	Port Lavaca, *Calhoun*	1934	280	30	357,106	2,795*y*	10,030*x*	30*x*
137	Port Neches 3,150 ft., *Orange*	1928	550	36	5,117,470	266,052	2,016*x*	167*x*
138	West Port Neches 5,944 ft., *Orange*	1936			113,191	66,117		
139	Powderhorn Lake, *Calhoun*	1939	0	*x*	0	0	0	0
	Raccoon Bend, *Austin*							
140	3,490 ft.	1927	1,458	600	17,023,466	400,000	*x*	525
141	4,120 ft.	1934	1,354		4,294,494	634,000		
142	Ray, *Bee*	1934	367	0	1,461,193	76,758	1,836	38
143	Refugio, *Refugio*	1922	1,025	Included with New Refugio		372,172	Included with New Refugio	
144	Refugio, New, *Refugio*	1934	1,000	2,720	39,242,931	1,089,808	300,942*x*	12,814±
145	Refugio Fox, *Refugio*	1932	150	Included with New Refugio			Included with New Refugio	
146	Rockland, *Jasper*	1929	20	0	30,858	0	*x*	*x*
147	Rosslyn, *Harris*	1938	40	0	23,603	14,102	*x*	*x*
148	Rosenberg, *Ft. Bend*	1939	250	0	6,000	6,000	30	30[1]
149	Sandy Point, *Brazoria*	1937	100	0	233,817	63,350	219	100[1]
150	Saratoga, *Hardin*	1901	538	0	29,099,708	326,559*y*	*x*	*x*
151	Sarco, *Goliad*	1938	20	0	1,165	0	*x*	*x*
152	Satsuma, *Harris*	1936	500	100	366,654	107,413	*y*	*y*
153	Schwab, *Polk*	1934	200	0	145,308	16,692	0	0
154	Schwab Wilcox, *Polk*	1939	200	0	67,282	67,282	0	0
155	Seabreeze, *Chambers*	1936	416	400	225,747	92,108	1,874	700[1]
	Segno, *Polk:*							
156	Deep	1938	360	0	503,681	435,000	*x*	*x*
157	Shallow	1936			1,629,439	530,000		
158	Silsbee, *Hardin*	1936	1,020	160	1,564,379	525,274	3,123	259
159	Slick, *Goliad, DeWitt*	1930	30	10	72,943	2,000	*x*	*x*
160	Sour Lake, *Hardin*	1902	946	0	79,395,185	402,760*y*	*x*	*x*
161	South China, *Jefferson*	1939	150	0	17,000	17,000	*x*	*x*
162	South Houston, *Harris*	1935	590	0	5,342,509	941,840	1,418	600[1]
163	South Liberty, *Liberty*	1925	345	0	15,587,177	140,000	*x*	*x*
164	Spanish Camp, *Wharton*	1936		1,280			*x*	2,096
165	Spindletop, *Jefferson*	1901	580	0	125,479,255	731,000	*x*	*x*
166	Spindletop Deep, *Jefferson*	1925						
167	Splendora, *Montgomery*	1934	100	0	996	0	*x*	0
168	Stratton Ridge, *Brazoria*	1932	25	0	12,214	0	*x*	0
169	Sugarland, *Ft. Bend*	1928	1,165	0	28,723,645	1,243,000	*x*	360
170	Telferner, *Victoria*	1937	30	40	33,722*y*	7,000	*x*	*x*
171	Texana, *Jackson*	1939	100	0	2,000	2,000	*x*	*x*
172	Thompsons, *Ft. Bend*	1931	5,100	0	34,287,213	4,399,000	17,000	2,000[1]
173	Thompsons-Vicksburg, *Ft. Bend*	1939			197,000	197,000		
174	Toland, *Refugio*	1939		40			*y*	*y*
175	Tomball, *Harris*	1933	8,400	1,200	13,925,985	2,528,000	42,796	20,000[1]
176	Tomoconnor, *Refugio*	1934	11,000	0	15,316,983	4,315,000	9,601	3,000[1]
177	Tuleta, *Bee*	1932	125	0	1,758,458	80,000	179	10[1]

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1939	During 1939		End of 1939			Number of Wells		Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
130					52		2	50	x	[2]		47.5	
131	47	3	0	10	34	3	33	1	2,053	1,872	0	25.0	y
132	252	9	11	0	79	x	15	64	355	[2]		27.6	
133	172	0	0	0	164	5	94	70	1,900	x		25	
134	12	0	0	0	0	1	0	0	2,450	x		55.8	
135	15	0	0	0	13	x	13	0	1,010	x		25	
136	13	0	5	6y	2	3	2	0	x	x	0	61.0	x
137	18	0	1	0	14	0	2	12	x	1,515	0	25.0	y
138	7	2	0	0	7	0	7	0				38.0	y
139	1	1	0	1	0	0	0	0	1,850	1,850	0		
140	160	0	0	0	80	1	1	79	275	[2]		28.2	
141	89	0	0	0	84	1	67	17	1,800	x		34.1	
142	43	0	6	0	11	0	0	11	1,755	[2]	0	46.0	
143	Included with New Refugio		y	y	35	x	11	24	550–2,000	y		33.0	
144	501y	14	y	y	103	x	91	12	1,500±	1,000±	0	39.0	
145	Included with New Refugio		y	y	18	x	15	3	700–2,000	y	0	38–42	
146	8	0	0	0	0	0	0	0	x	0		21	
147	1	0	0	0	1	0	1	0	1,800	y	0	39.3	
148	1	1	0	0	1	0	1	0	x	x		57	
149	8	0	3y	0	4	1	0	4	2,680	1,570		40.0	y
150	766	9	7	y	245	0	x	245y	x	x	0	20.0	y
151	1	0	0	0	1	0	1	0	x	x		35	
152	16	3	0		15	1	15	0	3,100	2,150	0	40.6	
153	3	0	0	0	3	0	3	0	x	x	0	39.0	
154	4	4	0	0	4	0	4	0	x	x	0	37.0	0.10
155	8	3	1	0	5	3	5	0	3,900		R[5]	40.0	0.07
156	74	30	0	2	32	0	31	1	950	x		36.8	
157					38	0	35	3	1,450	x		39.5	
158	48	10	0	0	44	2	41	3	574	550±		44.0	
159	5	0	0	0	1	x	1	0	550	x		46	
160	782x	0y	27	0y	166	0	4	162	x	x	0	20.0	y
161	3	3	0	0	3	0	3	0	x	x		36.5	
162	94	2	5	0	94	x	65	29	2,085y	2,019	0	25.6	
163	301	1	10	0	40	x	4	36	50	[2]		24	
164	8	2				8			1,300	1,250	0		
165	1,378	7	10	x	153	0	8	145	x	x	0	25	y
166												26	x
167	5	1	0	1	0	0	0	0	2,000	0		65	
168	4	0	0	0	0	0	0	0	x	0		29	
169	71	0	0	0	51	0	37	14	1,570	x		28	
170	3	0	0	0	2	x	2	0	900	x		27.8	
171	1	1	0	0	1	0	1	0	x	x		52	
172	291	52	0	0	256	x	227	29	2,430	x		25	
173					18		17	1	x	x		35.7	
174	1	1		1					2,520	2,520	0		
175	493	36	0	2	428	60	393	35	2,490	y		41	
176	409	44	0	0	404	x	403	1	1,040	x		35.5	
177	75	0	0	0	19	7	10	9	792	x		47	

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[5] Recycling.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
130	Cockfield (Pettus)	Eoc	S	32	3,616	3,926	15	DF	Mt. Selman	7,569
131	Marginulina	Olig	S	Por	4,690[1]	4,710[1]	16[1]	A	Hockleyensis	8,888
132	Miocene, Frio, Vicksburg	Mio, Olig	S	Por	3,780[1]	4,800[1]	*x*	Ds	Hockleyensis	7,165
133	Heterostegina, Frio	Olig	SH	Por	4,745	6,370	20	Af	Frio	7,242
134	Frio	Olig	S	Por	6,650	6,800	100	D	Frio	8,115[1]
135	Cockfield (Pettus)	Eoc	S	Por	3,036	4,277	*y*	NF	Cook Mtn.	4,256
136	Marginulina	Olig	S	Por	6,240	6,250	10[1]	DF	Frio	6,780
137	Miocene	Mio	S	Por	3,122	5,929	22[1]	Ds	Vicksburg	7,667
138	Frio	Olig	S	Por	5,920	5,942		Ds		
139	No Name	Mio	Sand	Por	4,625	*x*	*x*	Af	Mio, Olig	6,648
140	Whitsett, McElroy	Eoc	S	25	3,150	3,490	18	Df	Claiborne	7,068
141	Cockfield	Eoc	S	25	4,070	4,150	35			
142	Cockfield (Pettus)	Eoc	S		3,888	3,944	15[1]	Df	Yegua	4,253
143	Oakville, Catahoula, Frio	Mio, Olig	SH	Por	3,687	6,770	30[1]	Df	Vicksburg	9,225
144	Frio	Olig	SH	Por	4,900	6,600	30[1]	Df	Vicksburg	9,225
145	Marginulina	Olig	SH	Por	3,545	5,900	10[1]	D	Frio	7,300[1]
146	Cockfield	Eoc	S	Por	1,260	1,275	10	MF	Cook Mtn.	2,518
147	Yegua	Eoc	S	Por	6,947	6,956	9[1]	Af	Yegua	7,495
148	Cockfield	Eoc	Sand	Por	7,719	7,743	10	Ds	Cook Mtn.	8,698
149	Marginulina, Frio	Olig	S	30	6,480	6,500	15[1]	T	Vicksburg	8,943
150	Cap Rock, Lagarto, Miocene, Oligocene	Plio, Mio, Olig	SL	Por Cav	500	3,320	*x*	Ds	Yegua	7,461
151	Vicksburg	Olig	S	Por	5,013	5,023	*x*	D	Yegua	6,702
152	Yegua	Eoc	Sand	20	6,800	6,830	15	A	L Yegua	7,520
153	Yegua	Eoc	S	*x*	4,806	4,843	10	D	Wilcox	8,555
154	Wilcox	Eoc	S	22	7,786	7,799	10	D	Wilcox	8,555
155	Frio	Olig	Sand	25	8,110–8,460	8,475–8,600	25	D	Frio	8,888
156	Wilcox	Eoc	S	Por	8,100	8,150	30	D	Wilcox	9,154
157	Cockfield	Eoc	S	Por	5,000	5,200	10	D		
158	Cockfield	Eoc	S	Por	6,845[1]	6,965	20[1]±	Df	Yegua	7,778
159	Cockfield	Eoc	S	Por	4,240	4,404	10	D	Yegua	4,580
160	Pli, Mio, Mid-Olig, Jackson, Up. Saline Bayou	Pli, Mio, Olig	SH	Por	900[1]	4,000*y*	*x*	Ds	Yegua	7,914
161	Frio	Olig	Sand	Por	7,491	7,885	30	Ds	Frio	8,755
162	Miocene, Frio	Mio, Olig	S	30	4,600	4,775[1]	75[1]	Ds	Yegua	9,470
163	Miocene, Mid-Olig, Jackson, Yegua	Mio, Olig, Eoc	SH S	Por	700	4,996	100*x*	Ds	Upper Bayou Saline	5,174
164	Catahoula	Olig	S	Por	2,900	3,020[1]	30[1]+	A	Yegua	8,183
165	Cap Rock, Pliocene	Pre-Ter, Pli	L SH	Cav, Por	750	1,200	*x*	Ds	Vicksburg	7,382
166	Miocene, Mid-Oligocene, Frio	Mio, Olig	S	Por	2,920	5,900	69			
167	Cockfield	Eoc	S	Por	5,835	5,840	5	D	Cockfield	6,452
168	Miocene	Mio	S	Por	4,300	4,500	10	Ds	Mid-Olig	7,624
169	Heterostegina, Marginulina, Frio	Olig	S	25±	3,460	3,800	60	Ds	Vicksburg	7,042
170	Frio	Olig	S	Por	3,582	3,600	15	Df	Cook Mtn.	7,666
171	Frio	Olig	S	Por	5,686	5,770	10	Ds	Frio	8,001
172	Miocene, Marginulina, Frio	Mio, Olig	S	25	3,250	5,450	80	D	Vicksburg	8,539
173	Vicksburg	Olig	S	25	7,700	7,800	50			
174	Frio	Olig	S	Por	5,875[1]	5,890[1]	10[1]	*y*	Frio	7,010
175	Cockfield, Yegua	Eoc	S	25*x*	5,375	5,575	9	DF	Yegua	7,438
176	Frio	Olig	S	Por	5,500	5,900	100	Af	Frio	8,174
177	Cockfield (Pettus)	Eoc	SH	Por	3,065	4,183	11[1]	DF	Mt. Selman	6,062

below the top of that formation. The gas-oil ratio in the discovery well was 1:23,000, and the casing was perforated from 10,460 to 10,466 ft. This is probably the most important discovery of the area for the year.

Bammel-Aldine, Harris County.—This area was first discovered by the Lawrence No. 1 Zapp in April, 1937, but the discovery well produced only a small amount of distillate and gas from 6200 ft. During 1939 a thin oil sand was discovered at 7300 ft. in the Bammel area and about a 9-ft. oil zone at 6823 ft. in the Aldine area. Since this is the first oil production from the area, the year 1939 is given as the discovery year for oil. The gas production was discovered in the upper part of the Cockfield section, and the oil was found 360 ft. below the top of the Cockfield in the Aldine area and about 1100 ft. below the top in the Bammel area. The structure appears to be a large, gently dipping anticline, which was discovered by geophysics as early as 1928. The principal leaseholders are Texas Gulf Production Co., Stanolind, and Tide Water.

Buttermilk Slough, Matagorda County.—Buttermilk Slough field is 3½ miles southwest of the Palacios field, in southwestern Matagorda County. The prospect was discovered by the Sun company's reflection seismograph, and the same company drilled the discovery well. The Cavallin No. 1 was completed in August at a depth of 7860 ft. after plugging back from 9582 ft. The production is from the Frio formation,

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939
178	Tulsita, *Bee*	1938	0	10	4,000*y*	4,000	*x*	*y*
179	Turtle Bay, *Chambers*	1935	700	40	1,229,368	358,765	909*x*	300*x*
180	Vanderbilt, *Jackson*	1934	40	50	Incl. with West Ranch		*x*	*x*
181	Victoria, *Victoria*	1939	20	0	0	0	*x*	*x*
182	Voss, *Bee*	1936	80	0	75,047	2,000	*x*	*x*
183	Webster, *Harris*	1937	3,800	0	3,488,518	2,320,000	1,969	800[1]
184	Weser, *Goliad*	1936	100	0	2,556	0	*x*	*x*
185	West Beaumont, *Jefferson*	1936	705		1,960,945	1,077,263	*y*	*y*
186	West Columbia, *Brazoria*	1914	750	0	84,155,183	2,209,519*y*	*x*	441*y*
187	West Columbia, New, *Brazoria*	1937						
188	West Orange, *Orange*	1937	220	0	994,508	707,000	*x*	*x*
189	West Ranch, *Jackson*	1938	3,000	0	459,445	278,000	*x*	20[1]
190	White Creek, *Live Oak*	1939	100	0	32,000	32,000	*x*	*x*
191	Willow Slough, *Chambers*	1937	550	1,000	198,449	96,033		
192	Withers, *Wharton*	1936	3,800	6,200	3,188,626	1,406,411*y*	3,246*x*	844*x*
193	Withers, (Five Corners), *Wharton*							
194	Wilson Creek, *Matagorda*	1937	50	0	61,343	17,442	*x*	*x*
195	Worth, *Bee*	1935	50	0	27,275	*x*	*x*	*x*
196	Total		154,757*y*	31,415*y*	1,363,340,757	100,253,937[1]	695,171*x*	93,485*x*

which was topped at 7410 ft. The casing was perforated from 7850 to 7860 ft., and the well was completed producing 35 bbl. per day of 45° gravity oil with 35 per cent salt water through 11⁄64-in. choke, with a high gas-oil ratio. The principal leaseholder is the Sun company.

Caplen, Galveston County.—After drilling several dry holes on this reflection seismograph prospect, the Sun company, in March, completed the discovery well, Cade No. 2, from perforations 7474 to 7478 ft. after plugging back from 8011 ft. The initial production was 307 bbl. per day of 34° gravity oil through 11⁄64-in. choke, with a gas-oil ratio of 4803. The production is from the Discorbis zone of the Middle Oligocene. The field is on the Bolivar Peninsula, 3 miles west of the town of Caplen and 11 miles west of the High Island field. The Sun company is the principal leaseholder.

Chocolate Bayou, Brazoria County.—The Chocolate Bayou gas-distillate field was found by the Glen McCarthy No. 1, Houston Farms Development Co., in October after the area had been worked with reflection seismograph by Glen H. McCarthy, Inc. The discovery well was drilled to a depth of 10,385 ft. after encountering the top of the Frio at a reported depth of 8878 ft. The initial production was 25 bbl. a day of 51° gravity distillate from a reported depth of 9875 to 9878 feet.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1939	During 1939		End of 1939			Number of Wells						
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[e]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
178	3	1	0	0	1	*x*	0	1	1,450*y* @ 6,500′	*x*		45	
179	35	3	0	0	33	2	31	2	2,948	2,861	0	30.0	*x*
180	2	0	0	0	1	0	0	1	500	[2]		30.3	
181	1	1	0	0	0	1	0	0	*x*	*x*		*x*	
182	7	0	0	0	1	*x*	0	1	*x*	[2]		45	
183	195	89	0	0	195	0	192	3	950	*x*		29	
184	3	2	0	0	0	*x*	0	0	750	*x*		46.5	
185	58	6	4	0	48	10	30	18	*y*	*y*	0	27.0	*y*
186	316	4	1	0	41	0	7	34	*x*	1,115	0	20.0	*y*
187		12	0	0	67	0	61	6	2,452	2,099	0	28.0	*y*
188	Incl. Orange		0	0	47	0	47	0	*x*	*x*		35.8	
189	50	47	0	0	50	0	48	2	1,700	*x*		30.3	
190	8	8	0	0	8	0	0	8	*x*	*x*		22	
191	11	3	0	2	6	3	6	0	3,900		[5]	37.0	0.07
192	160	60	0	1	151	8	150	1	2,350	2,415	0	26.1	*y*
193									850	*x*	0	25.6	*y*
194	*x*	*x*	*x*	*x*	1	0	1	0	*x*	*x*		50	
195	2	0	0	2	0	0	0	0	850	*x*		30.3	
196	18,719	1,455	195	94	9,495	285	6,547	2,948					

Citrus Grove, Matagorda County.—The Citrus Grove gas field was first indicated by the Continental No. 1 Boecker in 1933. However, the well was not produced, and in July, 1939, the Continental No. 1 Savage was completed, producing 678 M cu. ft. of gas per day from a depth of 4142 ft. in the Miocene. The area is 6 miles east of the Palacios field. Principal leaseholders are Continental, Sun, Pure, and Magnolia.

Cologne, Victoria County.—The Cologne field was discovered by the Houston Oil Company's No. 1 Hornstein in September. The production is from a Catahoula sand of Miocene age, at a depth of 2870 ft. The initial production was 4000 M cu. ft. of gas per day. On Nov. 2, 1939, a Frio sand, found in another well, produced 129 bbl. per day of 27.5° gravity oil at a depth of 4832 ft. The field is 3 miles southwest of the Coletto Creek field. The principal leaseholders are Houston Oil, Phillips, and Shell.

Fannin, Goliad County.—The Fannin gas field was discovered in October by the Shell No. 1 Swickenheimer after geophysical work revealed the prospect. The production is from the Catahoula formation of Miocene age at a depth of 2855 ft. The initial production was 15,500 M cu. ft. of gas daily. This prospect is south of the town of Fannin. The principal leaseholders are Shell, Texas, Sun, and Magnolia.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
178	Cockfield (Pettus)	Eoc	SH	Por	3,564	3,590	26	DF	Cockfield	3,598
179	Marginulina	Olig	Sand	30	6,600	6,608	10[1]	D	Vicksburg	8,530
180	Frio	Olig	SH	Por	5,562	5,582	8	DF	Frio	7,042
181	Catahoula, Frio	Mio, Olig	S	Por	2,551 4,776	2,555 4,781	4[1] 10	F	Frio	5,523
182	Cockfield (Pettus)	Eoc	S	Por	3,985	4,017	5*y*	NF	U Yegua	4,306
183	Frio	Olig	S	30	5,750	6,082	100±	Ds	Frio	8,452
184	Yegua	Eoc	SH	Por	4,802 5,300	4,812 5,310	7[1]	MC	Cook Mtn.	5,313
185	Oligocene	Olig	Sands	30	5,800	5,810	10–20	D	L Frio	7,719[1]
186	Pli, Mio, Mid-Olig	Eoc, Plio, Mio	S	Por	2,601	3,741	250[1]±	Ds	Vicksburg	6,306[1]
187	Frio, Vicksburg	Olig	S	Por	5,200[1]	5,784[1]				
188	Frio	Olig	S	Por	5,585	6,123	8[1]	D	Frio	7,550
189	Frio	Olig	S	Por	5,086	5,780	40[1]	Ds	Frio	5,784[1]
190	Jackson	Eoc	S	Por	1,390	1,397	7[1]	ML	Jackson	1,785
191	Frio	Olig	Sand	25	8,346–8,650	8,490–8,860	20[1]	D	Frio	9,034[1]
192	Marginulina	Olig	S	Por	5,545	5,560	10[1]	Df	Frio	7,244[1]
193	Marginulina	Olig	S	Por	5,540	5,550	8[1]	Df	Frio	6,511[1]
194	Frio	Olig	S	Por	9,925	9,978	8[1]	Df	Frio	9,978[1]
195	Cockfield (Pettus)	Eoc	SH	Por		3,407	5	D	Pettus	3,705[1]
196										

Hillje, Wharton County.—The Hillje field is 6 miles south of the town of Hillje. It was discovered by reflection seismograph work by the Texas Company. No. 1 Peters was completed in September, producing gas and about 14 bbl. of 25° gravity oil per day from a *Marginulina* sand from 5220 to 5230 ft. The gas-oil ratio was 1:29,000. The Texas Company is the principal leaseholder.

Martha, Liberty County.—The Martha oil field is in the west central part of Liberty County, 3 miles northwest of Dayton. The Stanolind Oil and Gas Co. discovered the prospect by reflection seismograph and drilled the discovery well, No. 1 Flowers, in June. The well was drilled into the Upper Saline Bayou formation at a total depth of 9113 ft. and was plugged back to 8108 ft. in the Upper Cockfield, where it was completed producing 240 bbl. a day of 40° gravity oil from perforations 8104 to 8108 ft. The gas-oil ratio was 1:1990. The principal leaseholders are Stanolind, Pan American, Sun, Humble, and Continental.

Melon Creek, Refugio County.—The Melon Creek field was discovered as a result of subsurface geology, by the Copano Oil Co. It is immediately southwest of the Tomoconnor field. The discovery well, Copano No. 1-C Thos. O'Connor, was drilled to a depth of 5876 ft. and was completed in February, producing 108 bbl. a day of 37.6° gravity oil through perforations 5856 to 5876 ft. The production is from the Frio formation. The Humble, Quintana, and Copano oil companies are the principal leaseholders.

TABLE 2.—*Summary of Drilling Operations on Texas Gulf Coast*

Important Wildcats Drilled in 1939

	County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Survey			
1	Aransas	Orrick	7,360	Recent	Frio
2	Brazoria	J. de J. Valderas	10,538	Beaumont clay	Frio
3	Brazoria	Perry & Austin	10,385	Beaumont clay	Frio
4	Fort Bend	Meyer	7,743	Beaumont clay	Claiborne
5	Fort Bend	H. Chrisman	7,800	Beaumont clay	Vicksburg
6	Galveston	Dickson	7,514	Recent	Discorbis
7	Harris	W. S. Powell	6,520	Lissie	Yegua
8	Jackson	Green	7,967	Beaumont clay	Frio
9	Jackson	Musquiz Gr.	5,543	Beaumont clay	Frio
10	Jefferson	McFaddin	2,397	Recent	Miocene
11	Jefferson	Smith	6,648	Beaumont clay	Frio
12	Jefferson	H & TB R.R.	7,885	Beaumont clay	Frio
13	Liberty	McNeil	7,612	Beaumont clay	Upper Saline Bayou
14	Liberty	I. & G. N.	8,108	Beaumont clay	Yegua
15	Polk	G. S. Thomas	7,788	Legarto	Wilcox
16	Refugio	Aldrete Gr.	5,714	Beaumont clay	Frio
17	Refugio	Aldrete Gr.	5,415	Beaumont clay	Frio
18	Refugio	Aldrete Gr.	6,112	Beaumont clay	Frio
19	Refugio	Hoyt	5,875	Beaumont clay	Frio

Rosenberg, Fort Bend County.—The Rosenberg field, 2 miles east of the town of Rosenberg, was discovered by H. C. Cockburn with his No. 1 Dzierzanowski. The well blew out at 7743 ft., and the drill stem was cemented at 7719 ft. to kill the gas flow. The initial production was 1000 M cu. ft. of gas and 30 bbl. of 61° gravity distillate per day. The production is from the Cockfield or Upper Saline Bayou, 330 ft. below the top of the Cockfield. The discovery is attributed to geophysical work. Cockburn, Humble, Sun, Gulf, and Shell, all have interests in the area.

South China, Jefferson County.—South China field is 2½ miles northwest of the town of Cheek and 10 miles southwest of Beaumont. The discovery well was drilled by Hebert, Smith, and Echols in June and was completed through perforations from 7872 to 7885 ft. in the Frio after plugging back from a total depth of 8753 ft. The initial production was 106 bbl. of 37.5° gravity oil per day through a 9/64-in. choke, with a low gas-oil ratio. The principal leaseholders are Hebert, Smith and Echols, Magnolia, and Sun companies.

Texana, Jackson County.—The Texana gas-distillate field was the result of a wildcat well drilled by Moore and Ahern. Their No. 1 Drushel was drilled to a total depth of 7005 ft. and plugged back to 5708 ft. The casing was perforated from 5705 to 5708 ft., and the initial production was 1500 M cu. ft. of gas and 15 bbl. of 52° gravity distillate per day. This production is from a sand in the Frio. The principal

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Culton—Barry tract	46		1/8	2,250	2,000	New sand, McCampbell
2	Glenn McCarthy—Carr tract	180		11/64	Sealed	3,400	Discovery, Angleton
3	Glenn McCarthy—Houston Farms Dev. tract	25		1/4 & 1/64	Sealed	1,600	Discovery, Chocolate Bayou
4	H. C. Cockburn—Dzierzanowski tract	112		7/32	1,500	1,500	Discovery, Rosenberg
5	H. M. Taylor—Musselman tract	926		1/4	1,700	1,800	Discovery, Thompson-Vicksburg
6	Sun Oil Co.—Cade tract	307		11/64	Sealed	2,200	Discovery, Caplen
7	Union Producing Co.—Rash tract		55	1/8	2,450	2,425	New sand, Fairbanks
8	Crosby—Kopnickey tract	156		10/64	2,750	2,400	New sand, Francitas
9	Glasscock—Drummond tract	187		9/64	925	550	New sand, West
10	Shell Petroleum Corp.—State tract	150		1/4	550	50 to 75	New sand, Clam Lake
11	Gulf—Thomas tract	178		3/16	3,000	2,875	New sand, Fannett
12	Geo. Echols & H. Smith—Fontenot tract	106		9/64	1,000	1,250	Discovery, South China
13	General Crude—Fee tract	768		1/4	1,250	1,175	New sand, Esperson
14	Stanolind—Flowers tract	240		5/32	1,580	1,400	Discovery, Martha
15	Peyton Bros.—Kirby-West tract	185		1/8	2,150	650	Discovery, Ace-Wilcox
16	Morgan-Gulf—Rook tract	113		1/8	1,350	700	New sand, La Rosa
17	Morgan-Gulf—Rook tract	126		1/8	975	635	New sand, La Rosa
18	Rutherford—Schiermer tract	154		1/8	925	610	New sand, La Rosa
19	Copana Oil Co.—Thos. O'Connor tract	108		1/8	1,850	900	Discovery, Melon Creek

leaseholders are Moore and Ahern, S. W. Richardson, Magnolia, Sinclair-Prairie, Gulf, and Stanolind.

Toland, Refugio County.—The Toland gas-distillate one-well field lies between the LaRosa and Bonnie View fields. It was discovered in September by the Phillips Petroleum Co. No. 1 Toland. The well was drilled to a depth of 7010 ft. and plugged back to 5920 ft. The casing was perforated from 5870 to 5880 ft., and the well was completed producing 1200 M cu. ft. of gas and 25 bbl. of 58° gravity distillate a day from the Frio. The field is entirely owned by independent companies.

White Creek, Live Oak County.—The White Creek field is south of the Ezzell field. The discovery well on this prospect was drilled in February by Holland and Smith. Their No. 1 Gayle was completed pumping 27 bbl. a day from a sand 1390 to 1397 ft. The gravity of the oil is 21°. Besides the discoverer, Edwin M. Jones has a large interest in this field.

Victoria, Victoria County.—John G. Mayo's No. 1 Voight was the discovery well for the Victoria field. The production is from a sand in the Catahoula from 2551 to 2555 ft. The initial production was 500 M cu. ft. of gas and 10 bbl. a day of 20.5° gravity oil. The field is

TABLE 3.—*New Sands Discovered during* 1939 *on the Texas Gulf Coast*

Field	Depth, Ft.	Age	Kind
Ace	7,800	Wilcox	Oil
Bonnie View	4,200	Discorbis	Gas
Clam Lake	3,800	Miocene	Oil
Esperson	7,000	Upper Saline Bayou	Oil
Fairbanks	7,000	Upper Saline Bayou	Distillate
Fannett	7,700	Frio	Distillate
Fox	6,461	Frio	Oil
Francitas	7,950	Frio	Oil
Hardin	7,680	Upper Saline Bayou	Gas
Keeran	4,806	Frio	Gas
Keeran	6,082	Frio	Oil
LaRosa	5,415	Frio	Oil
LaRosa	5,714	Frio	Oil
LaRosa	5,855	Frio	Oil
LaRosa	6,112	Frio	Oil
LaRosa	6,327	Frio	Oil
Lovell Lake	7,780	Frio	Oil
McCampbell	7,354	Frio	Distillate
McFaddin	4,400	Heterostegina	Oil
McFaddin	5,300	Frio	Oil
Thompsons	4,345	Miocene	Oil
Thompsons	7,700	Vicksburg	Oil
Turtle Bay	6,550	Marginulina	Oil
Van Vleck	8,500	Frio	Oil
West	5,550	Frio	Oil

2 miles south of the town of Victoria. The principal owners are Shell, Sun, and Magnolia oil companies.

NEW SANDS

New sands contributed considerably to the reserves for the year (Table 3). The most important new sand discoveries were the Wilcox at Ace and the Vicksburg at Thompsons.

Extensions to the producing areas or horizons were recorded at Anahuac, Cotton Lake, Eureka, Clear Lake, Cordele, Fairbanks, Segno, West, McCampbell, Tomoconnor, Clara Driscoll, East White Point, McFaddin, and Plymouth.

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Oil and Gas Development and Production in North Texas for the Year 1939

By Lewis W. MacNaughton,* Member A.I.M.E.

(New York Meeting, February 1940)

The North Texas district, as herein defined, includes the counties of Archer, Baylor, Clay, Cooke, Foard, Hardeman, Knox, Montague, Wichita, and Wilbarger. This area covers generally the crest and south flank of a system of buried mountains known as the Red River uplift. The oil and gas accumulations along this feature are in traps, which, although localized by structures incident to the regional uplift, are usually modified by stratigraphic changes in the sediments. Excepting the fields in southeastern Baylor, southern Archer, and southwestern Clay counties, all the fields within the district are on this Red River uplift. These exceptions, which have the same type of oil and gas accumulation as the other fields, are on the extreme north end of the Bend arch, which is a broad anticline plunging northward from the Llano uplift in central Texas to Archer County. The larger part of past oil and gas production has come from Pennsylvanian strata, with less important amounts from the Permian, and minor but increasingly important quantities from the Ordovician.

Developments during 1939

With the later stages of development being reached in the K.M.A. field during the first half of the year, some 400 fewer producing wells were drilled in North Texas in 1939 than in 1938, when some 1750 wells were drilled. Despite this decrease in activity, production in 1939 increased about 3½ million barrels over 1938 figures, and at the end of the year the oil reserves were somewhat larger than on the first of the year. As is usually characteristic of the district, this resulted from the discovery of a large number of relatively unimportant fields.

Owing principally to no appreciable abatement in wildcat drilling, more new fields and extensions to old fields were discovered this year. Although none of these discoveries was of such magnitude as to be important to the oil industry, the new developments in Montague and Cooke Counties portend greater and probably more important operations in these areas.

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TABLE 1.—*Oil and Gas Production in North Texas*

Line Number	*County*, Field	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.	
								During 1939		End of 1939			Number of Wells			
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939
1	*Archer:* Carson	1939	30	0	*y*	*y*	4	3	1	*y*	*y*	*y*	*y*	*y*	*x*	*x*
2	Chalk Hill	1931	600	0	2,332,372[1]	298,823	41	0	0	*y*	4*y*	0	0	4*y*	900	480
3	Chambers	1939	20	0	*y*	*y*	1	1	0	0	1	0	*y*	*y*	*x*	*x*
4	Colgan	1939	60	0	362	362	5	5	1	0	5	0	0	5	*x*	*x*
5	Frarley	1939	20	0	*y*	*y*	2	2	0	*y*	*y*	0	*y*	*y*	*x*	*x*
6	Griffin	1939	100	0	9,650	9,650	6	6	*y*	0	*y*	0	*y*	*y*	*x*	*x*
7	Hart	1939	40	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	0	*y*	*y*	*x*	*x*
8	Holliday	1937[2]	300[2]	0	98,434[2]	114,491	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
9	Hull-Silk	1938	2,800	0	435,889	387,224	93	79	*y*	*y*	9*y*	0	9*y*	*y*	*x*	*x*
10	Kadane	1939	80	0	1,125	1,125	1	1	0	*y*	*y*	0	*y*	*y*	*x*	*x*
11	Mankins	1939	160	0	23,938	23,938	3	3	0	0	3	0	*y*	*y*	*x*	*x*
12	Morrison	1939	20	0	*y*	*y*	2	2	0	*y*	*y*	0	*y*	*y*	*x*	*x*
13	All other fields		*y*	0	113,838,418[3]	3,092,306[3]	6,85*y*	255	121	*y*	*y*	*y*	*y*	*y*		
14	*Baylor:* Portwood	1924	600	0	4,366,908	350,637	188	6	8	*y*	16*y*	0	0	16*y*	*x*	*x*
15	Seymour	1939	400	0	35,578	35,578	10	10	0	0	10	0	*y*	*y*	*x*	*x*
16	*Clay:* Burns	1939	160	0	33,640	33,640	2	2	0	0	2	0	2	0	*x*	*x*
17	Costley	1939	80	0	0	0	3	3	*y*	*y*	*y*	0	*y*	*y*	*x*	*x*
18	Halsell	1939	80	0	11,131	11,131	2	2	0	0	2	0	2	0	*x*	*x*
19	Henderson	1939	40	0	0	0	1	1	0	1	0	0	0	0	*x*	*x*
20	Jolly	1939	40	0	932	932	1	1	0	0	1	0	1	0	*x*	*x*
21	Kinder	1939	40	0	837	837	1	1	0	0	1	0	1	0	*x*	*x*
22	Petrolia	1902	1,100	4,000	7,857,578	681,054	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
23	Worsham	1937	200	0	392,204	71,588	13	2	1	0	6	0	*y*	*y*	*x*	*x*
24	*Cooke:* Bruhlmeyer	1935	*y*	*y*	2,811,002	355,405	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
25	Callisburg	1939	20	0	2,481	2,481	1	1	0	0	1	0	*y*	*y*	*x*	*x*
26	T.C.U.	1939	100	0	1,115	1,115	2	2	0	*y*	*y*	0	*y*	*y*	*x*	*x*
27	Voth	1938	200	20	88,634	88,634	24	24	*y*	0	23	1	*y*	*y*	*x*	*x*
28	Walnut Bend	1938	350	0	271,273	253,386	30	28	0	0	30	0	30	0	2,360	*y*
29	All other fields		*y*	*y*	13,954,896	1,239,273	*y*	1*yy*	4*y*	*y*	*y*	*y*	*y*	*y*		
30	*Foard:* Johnson	1933	450	120	1,351,331	152,958	15	1	3	0	7	3	10	0	*x*	*x*
31	Thalia	1927	80	*y*	303,453	13,714	13	0	*y*	*y*	3	2	0	3	*x*	*x*
32	*Montague:* Benton and Holmes	1939	500	0	23,793	23,793	7	7	0	0	7	0	7	0	*x*	*x*
33	Nocona Townsite	1939	640	0	55,506	55,506	9	9	0	0	9	0	*y*	*y*	*x*	*x*
34	All other fields		*y*	*y*	30,108,713	1,804,501	1,093	36	16	*y*	*y*	*y*	*y*	*y*		
35	*Wichita:* K.M.A. (Wichita and Archer)	1931	25,000	0	13,993,704	8,207,319	1,178	*y*	*y*	*y*	*y*	0	*y*	*y*	2,*yyy*	1,0*yy*
36	State Hospital	1938	40	0	27,867	16,937	2	1	0	0	2	0	*y*	*y*	*x*	*x*
37	Underwood	1939	60	0	0	0	6	6	0	6	0	0	0	0	*x*	*x*

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[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] From 1-1-33.

[2] Canyon production only.

[3] Includes production of fields listed having *y* production.

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
								Depth, Avg. Ft.					
		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1		40.0	*y*	Gunsight	Pen	S	Por	1,490	1,510	3	*y*	*y*	*y*
2	RP	42.0	*y*	Canyon	Pen	S	Por	2,200	2,225	20	A	Strawn	5,748
3		*y*	*y*	Gunsight	Pen	S	Por	921	925	4	*y*	Cisco	925
4		40.0	*y*	Gunsight	Pen	S	Por	1,453	1,461	8	*y*	Cisco	1,461
5		40.0	*y*	Gunsight	Pen	S	Por	920	925	4	*y*	Gunsight	925
6		42.0	*y*	Cisco Strawn	Pen Pen	S S	Por Por	1,630 4,390	1,640 4,410	8 24	*y* *y*	Strawn	4,439
7		*y*	*y*	Gunsight	Pen	S	Por	900	910	7	*y*	*y*	*y*
8		*y*	*y*	*y* Canyon	Pen Pen	S S	Por Por	675 2,600	682 2,630	6 10	*y* *y*	*y*	4,537
9		*y*	*y*	Cisco Strawn	Pen	S S L	Por Por Por	1,300 3,800 4,320	1,320 3,860 4,350	5 15 30	*y*	*y*	*y*
10		40.0	*y*	Smithwick (Bend)	Pen	L	Por	5,170	5,280	30	*y*	Bend	5,284
11		43.0	*y*	Caddo	Pen	L	Por	4,660	4,690	30	*y*	Caddo	4,696
12		*y*	*y*	Gunsight	Pen	S	Por	1,290	1,300	4	*y*	Gunsight	1,293
13													
14		36.5	*y*	Gunsight	Pen	S	Por	1,400	*y*	10 ±	*y*	Strawn	4,265
15		*y*	*y*	Upper Canyon	Pen	*y*	Por	2,580	2,725	20	*y*	*y*	3,400
16		44.0	*y*	Strawn	Pen	S	Por	4,425	4,450	36	*y*	Strawn	4,461
17		41.0 38.0	*y*	Cisco	Pen	S S	Por Por	1,035 1,150	1,050 1,160	18	*y*	Cisco	1,176
18		38.0	*y*	Lower Strawn	Pen	S	Por	4,750	4,790	42	*y*	Lower Strawn	4,793
19		*y*	*y*	Upper Strawn	Pen	S	Por	3,420	3,430	12	*y*	Upper Strawn	3,432
20		41.0	*y*	Smithwick	Pen	L	Por	5,350	5,400	40	*y*	Bend	5,400
21		37.0	*y*	Lower Strawn	Pen	S	Por	4,130	4,150	25	*y*	*y*	5,527
22		36.0	*y*	*y*	Pen	S	Por	1,500	*y*	10 ±	*y*	Cam-Ord	4,289
23		38.0	*y*	Strawn	Pen	S S	Por Por	3,400 3,900	3,440 3,950	10 26	*y*	Strawn	*y*
24		41.0	*y*	*y*	Pen	*y*	*y*	2,000	*y*	15	*y*	Pennsylvania	2,500
25		47.0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
26		30.0	*y*	*y*	Pen	*y*	*y*	1,125	1,140	15	*y*	*y*	1,143
27		38.9 gas	*y*	Ellenburger	Ord	S L	Por Por	1,620 1,725	1,630 1,735	10 15	*y*	Ellenburger	1,793
28		35.3	*y*	Strawn Simpson	Pen Ord	S *y*	20	4,900 5,200	4,970 5,240	25 ±	*y*	Cam-Ord	6,055
29													
30		*y*	*y*	Canyon	Pen	SL	Por	3,600	3,625	*y*	*y*	Pre-Cam	5,003
31		39.0	*y*	(Thalia) Cisco	Pen Pen	S L	Por	2,500	2,550	*y*	*y*	Pre-Cam	2,550
32		38.0 40.0	*y* *y* *y*	Upper Strawn Canyon Lower Strawn	Pen Pen Pen	S S S	Por Por Por	2,900 2,020 3,400	2,960 2,030 3,870	25 10 20	*y* *y* *y*	Pre-Cam	3,855
33		43.0 43.0 40.0	*y* *y* *y*	Upper Strawn Lower Strawn Caddo	Pen Pen Pen	S S L	Por Por Por	4,280 4,650 5,230	4,300 4,680 5,250	*y* *y* *y*	*y*	Caddo	5,249
34													
35		40.0	*y*	Strawn	Pen	SL	Por	3,800	3,850	25 ±	AM	*y*	*y*
36		*y*	*y*	Bend	Pen	L	Por	5,110	5,150	27	*y*	Bend	5,375
37		40.0	*y*	Cisco	Pen	S	Por	1,200	1,210	6	*y*	Cisco	1,207

TABLE 1.—(*Continued*)

Line Number	*County,* Field	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.	
								During 1939		End of 1939			Number of Wells			
			Oil	Gas[b]	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939
38	All other fields..		*y*	*y*	297,328,664	5,327,421	11,532		1*yy*	*y*	*y*	*y*	*y*	*y*		
39	*Wilbarger:* Castleberry..............	1938	300	0	119,099	87,108	20	12	0	0	18	0	18	0	*x*	*x*
40	Consolidated....	1939	600	0	17,940	17,940	8	8	0	0	8	0	8	0	*x*	*x*
41	Lido............	1939	20	0	0	0	1	1	0	1	0	0	0	0	*x*	*x*
42	Phillip-King....	1938	80	0	30,465	24,408	4	1	0	0	4	0	*y*	*y*	*x*	*x*
43	Pois-Schultz....	1939	100	0	9,171	9,171	6	6	0	0	6	0	*y*	*y*	*x*	*x*
44	All other fields..		*y*	*y*	67,936,829	2,684,946	2,027	44	19	*y*	*y*	*y*	*y*	*y*		
45	Total.........		*y*	*y*	557,874,932	25,479,332	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*		

Line Number	Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
								Depth, Avg. Ft.					
		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
38													
39		*y*	*y*	Cisco Canyon	Pen Pen	S S L	Por Por Por	2,170 2,640 3,190	2,190 2,650 3,210	9 9 15	*y*	Canyon	3,200
40		40.0	*y*	Upper Strawn Lower Strawn	Pen Pen	S S	Por Por	3,750 4,025	3,770 4,065	22 40	*y*	Lower Strawn	4,065
41		38.0	*y*	Strawn	Pen	S	Por	3,635	3,660	25	*y*	Strawn	3,660
42		*y*	*y*	Cisco Canyon	Pen Pen	S L	Por Por	2,500 2,550	*y*	*y*	*y*	*y*	*y*
43		38.0	*y*	Cisco	Pen	S S S	Por Por Por	1,235 1,665 1,885	1,245 1,685 1,900	10 20 15	*y*	Cisco	1,909
44													
45													

Pressure maintenance in the K.M.A. field is now approaching a field-wide basis. Since this project involves cooperation among 143 operators, who own nearly 1200 producing wells in this 25,000-acre field, it is the largest program of its kind ever undertaken in the history of the oil business. When the project is fully under way, there will be five natural gasoline and recycling plants where the residue gas will be returned to the field through a hundred or more input wells under pressures ranging from 1200 to 1800 lb. per sq. in. This work is administered by the

TABLE 2.—*Summary of Drilling Operations in North Texas*

Discoveries, Extensions, and Important Wildcats Drilled during 1939

	Field	County	Drilled by	Well Number and Farm	Survey	Producing Formation
1	Carson	Archer	Cree & Hoover	Turbeville, J. H. No. 1	Carson, Robt.	Gunsight
2	Chambers	Archer	Chambers & Hanks	Andrews, R. O. No. 1	T. E. & L. Co.	Gunsight
3	Colgan	Archer	Shell Oil Co.	Colgan E. No. 1	Martin, J. F.	Gunsight
4	Frarley	Archer	Burns, P. C.	Andrews, N. I. No. 1	Frarley, G. C.	Gunsight
5	Griffin	Archer	Deep Oil Dev. Co.	Waggoner Est. No. 1	H. & T. C. R. R. Co.	Lower Strawn
6	Griffin	Archer	Griffin, E. P.	Waggoner Est. No. 1	H. & T. C. R. R. Co.	Gunsight
7	Hart	Archer	Hart & Norwood	Carpenter J. D. No. 1	Clark & Plumb Subd.	Gunsight
8	Hull-Silk	Archer	Ligon, Bert	Moss No. 3-B	H. & T. B. R. R.	Cisco
9	Hull-Silk	Archer	Sikes, Louis	Ford No. 1	Cecil, T.	Strawn
10	Kadane	Archer	Kadane, G. E. & Sons	Hemmi, J. A. No. 1	Clark & Plumb Subd.	Smithwick
11	Mankins	Archer	British American	Wilson, T. B. No. 1	H. & T. C. R. R. Co.	Caddo
12	Seymour	Baylor	British American	Green, F. C. No. 1-D	T. & N. O. R. R. Co.	Upper Canyon
13	Burns	Clay	Burns, L. T.	Browning, A. L. No. 1	Yearly, W. W.	Strawn
14	Costley	Clay	Costley, E. N. et al.	Taylor, C. T. Est. No. 1-C	Bacon Subd.	Cisco
15	Halsell	Clay	Bridwell Oil Co.	Halsell, F. No. 1	W. C. R. R.	Strawn
16	Henderson	Clay	Shell Oil Co.	Henderson H. No. 1	T. E. & L. Co.	Upper Strawn
17	Jolly	Clay	Continental-Superior	Ross O. O. No. 1	Walker W.	Smithwick
18	Kinder	Clay	Sinclair, Frabor-Hodges	Kinder L. No. 1	Clark & Plumb	Lower Strawn
19	Callisburg	Cooke	Big Indian Oil Co.	Davis, B. W. No. 1	Fannin C. S. L.	Pennsylvanian
20	Hood	Cooke	Pois & Schulz	Felker, E. A. No. 1	Taylor, J.	Strawn
21	Morton	Cooke	Big Indian Oil Co.	Morton, M. P. No. 1	E. T. R. R. A-365	Strawn
22	South Muenster	Cooke	Roberts J. C. et al.	Truebenbach No. 1	Littleton, J. C.	Pennsylvanian
23	T. C. U.	Cooke	Russell & Lawson	T. C. U. et al. No. 1	Linn, W. A.	Cisco
24	Voth	Cooke	Whitfield et al.	Voth, B. No. 2	Fulton Z. D.	Ellenburger
25	Walnut Bend	Cooke	Sinclair	Best No. 10	Toby & Ward	Ellenburger
26	Benton and Holmes	Montague	Benton & Holmes	Bowers, J. No. 1	M. E. P. & P. R. R.	Upper Strawn
27	Benton and Holmes	Montague	United Producers	Braman, D. H. No. 1	Jacques	Lower Strawn
28	Nocona	Montague	Rogers & Rogers	Burnett, J. E. A. No. 1	Leonaw, J.	Lower Strawn
29	Nocona	Montague	Stanolind	Davis No. 2	Wells, W. J.	Caddo
30	Nocona	Montague	Youngblood & Foree	Davis No. 1	Jennings, J. D.	Upper Strawn
31		Montague	Gant, W. & Continental Oil	Brown, Mrs. J. L. No. 1	Blair, J. F.	y
32	K. M. A.	Wichita	E. C. Oil Co.	Burnside, A. W. No. 3-C	Sharp, J. M.	Canyon
33	K. M. A.	Wichita	Hanlon & Buchanon, Inc.	Collins, C. F. No. 1-A	Brown, R.	Gunsight
34	Underwood	Wichita	Underwood	Rogers, W. P. No. 1	Wheelwright, G.	Cisco
35	Consolidated	Wilbarger	Consolidated Oil	Waggoner No. 1-CC	H. & T. C.	Lower Strawn
36	Consolidated	Wilbarger	Consolidated Oil	Waggoner No. 1-CC	H. & T. C.	Upper Strawn
37	Lido	Wilbarger	Lido Oil Co.	Waggoner No. 21-C	H. & T. C.	Upper Strawn
38	Pois-Schulz	Wilbarger	Pois & Schulz	King, J. P. No. 1	D. L. & C. Co.	Cisco

K.M.A. Pressure Maintenance Association, which is headed by an executive committee composed of 15 operators.

OUTLOOK FOR 1940

In regions like North Texas, where the oil and gas fields are partly controlled by stratigraphic conditions, the collecting of accurate subsurface geological information becomes very important. As more and

TABLE 2.—(*Continued*)

Discoveries, Extensions, and Important Wildcats Drilled during 1939

	Depth Completed, Ft.	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	1,491–1,494	1,507	Permian	Gunsight	58	*x*				New field
2	905–907	907	Permian	Gunsight	21	*x*		*x*	*x*	New field
3	1,453–1,461	1,461	Permian	Gunsight	100	*x*				New field
4	921–925	925	Permian	Gunsight	102	*x*		Pumping		New field
5	4,393–4,410	4,410	Permian	Lower Strawn	4	*x*				Opened deep production
6	1,628–1,638	4,410	Permian	Lower Strawn	760	*y*			30	Opened shallow production
7	905–907	909	Permian	Gunsight	72	*x*		*x*	*x*	Extension
8	1,285–1,293	1,293	Permian	Cisco	64	*y*	*y*	*y*	*y*	Shallow Hull-Silk pay
9	4,375–4,402	4,402	Permian	Strawn	200	*y*	*y*	*y*	*y*	Northeast extension to Hull-Silk
10	5,164–5,284	5,284	Permian	Smithwick	165	*x*		*x*	*x*	New horizon
11	4,666–4,696	4,696	Permian	Caddo	127	*x*		*x*	*x*	Deep
12	2,580–2,605	2,605	Permian	Upper Canyon	260	*x*		*x*	*x*	New field
13	4,432–4,461	4,461	Permian	Strawn	900	*y*		*y*	*y*	New field
14	1,050–1,074	1,074	Permian	Cisco	240	*y*		*y*	*y*	New field
15	4,754–4,793	4,793	Permian	Strawn	1,272	*y*		*y*	*y*	New field
16	3,419–3,432	3,432	Permian	Upper Strawn						New field
17	5,342–5,400	5,400	Permian	Smithwick	1,136	0.64		*y*	*y*	New field
18	4,130–4,158	4,160	Permian	Lower Strawn	150	*y*		*y*	*y*	New field
19	3,519–3,529	*y*	Comanchean	*y*	*y*	*y*		*y*	*y*	New field
20	1,156–1,196 1,201–1,211	1,750	Comanchean	*y*	*y*	*y*		*y*	*y*	Abandoned oil well
21	2,509–2,517	2,517	Comanchean	Strawn	25	*x*		Pumping		Abandoned oil well
22	1,657–1,670	*y*	Comanchean	*y*	9	*x*		*y*	*y*	New field
23	1,125–1,143	1,143	Comanchean	Cisco	109	*x*		*y*	*y*	New field
24	1,783–1,793	1,793	Comanchean	Ellenburger	436	*x*		*y*	*y*	New field
25	5,230–5,265	5,265	Comanchean	Ellenburger	664	*y*		*y*	*y*	New deep test
26	2,887–2,958	2,958	Comanchean	Upper Strawn	523	*y*		*y*	*y*	New field
27	3,460–3,509	3,844	Comanchean	Lower Strawn	204	*y*		*y*	*y*	New field
28	4,639–4,658	4,658	Pennsylvanian	Lower Strawn	523	*y*		*y*	*y*	New deep well
29	5,230–5,255	5,255	Pennsylvanian	Caddo	1,920	*y*		*y*	*y*	New deep well
30	4,278–4,304	4,338	Pennsylvanian	Upper Strawn	150	*y*		*y*	*y*	New deep well
31	*y*	7,341	Pennsylvanian	Ellenburger	*x*	*x*		*x*	*x*	Deepest Montague Co. test
32	2,930–2,965	2,965	Permian	Canyon	8	*y*		*y*	*y*	New Canyon pay
33	1,710–1,718	1,718	Permian	Gunsight	264	*y*		*y*	*y*	New Cisco pay
34	1,200–1,206	1,207	Permian	Cisco	25	*y*		*y*	*y*	New field
35	4,026–4,065	4,065	Permian	Lower Strawn	248	*y*		*y*	*y*	New field
36	3,750–3,775	3,775	Permian	Lower Strawn	*y*	*y*		*y*	*y*	New field
37	3,635–3,660	3,660	Permian	Upper Strawn	285	*y*		*y*	*y*	New field
38	1,888–1,902 1,667–1,684 1,236–1,245	1,902	Permian	Cisco	388 913 5	*y*		*y*	*y*	New field

Number of oil wells completed during 1939	1,300
Number of gas wells completed during 1939	5
Number of dry holes completed during 1939	443

better geological data become available, the chances of finding new producing areas increase. Since such information is being collected, and because of the recent developments in Montague and Cooke Counties, prospects of finding further reserves in 1940 appear good.

Acknowledgments

The writer wishes to thank F. L. Burchard, H. B. Fuqua, and D. V. Carter for information and assistance rendered.

Oil and Gas Development in North Central Texas for 1939

By H. W. Imholz*

(New York Meeting, February 1940)

The Palo Pinto limestone pools of Jones and Shackelford Counties were defined and almost fully developed during the year. A new Palo Pinto limestone pool was apparently discovered when the K. B. Nowels No. 1 Pardue, S.F.I. and W. survey, south central Haskell County, was completed for a small well in Palo Pinto limestone at 3395 to 3421 feet.

In Haskell County, Amerada Petroleum Corporation's C. J. Kleiner, J. M. Cass survey, drilled to the Ellenburger with a total depth of 5607 ft., where it was abandoned.

A Bluff Creek sand field of undetermined size was discovered by the Fain-McGaha No. 1 Dawson-Conway, P. G. Holcomb survey, which was completed for 37 bbl. at 1496 feet.

The Cook field was extended by the Roeser-Pendleton B-113 Cook in sec. 113, E.T.R.R. Co. survey, the well being completed for 510 bbl. from Cook sand encountered at 1545 to 1568 feet.

Several shallow pools of minor importance were also discovered in Shackelford County during the year.

In Jones County the Lewis and the Steffens fields, in block 15, T. and P.R.R. Co. survey, were further developed during the year but the limits of the Steffens field were not definitely defined. The most important discovery in Jones County was the Guitar field, where most of the wells that had been producing from the Cook sand were deepened to the Hope limestone, a new producing horizon.

In Taylor County, the Bowles field, sec. 28, B.A.L. survey, was defined and proved to be of minor importance.

The Goldsboro and Novice area, in northwest Coleman County, continued to hold considerable interest because of the developments near the town of Novice, where new leases continued to be opened for production.

Nolan County was placed in the ranks of the producing counties when the S. B. Owens No. 1 Tipton, sec. 43, block 19, T. and P.R.R. Co. survey,

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Summarized at meeting; manuscript received at the office of the Institute April 3, 1940.

* Consulting Geologist, Abilene, Texas.

TABLE 1.—*Oil and Gas Production in North Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres, Oil	Total Oil Production, Bbl. To End of 1939	Total Oil Production, Bbl. During 1939
1	Bull Allcorn, *Brown*	1927	100	130,535	4,500
2	Byler, *Brown*	1926	290	844,339	9,222
3	Byrd, *Brown*	1920	250	402,810	4,418
4	Childress, *Brown*	1927	180	869,077	43,034
5	Clark-Buffalo, *Brown*	1927	460	791,446	16,126
6	Cross Cut, *Brown*	1921	2,300	6,233,176	108,021
7	Fry, *Brown*	1925	940	7,791,947	81,242
8	George, *Brown*	1927	200	784,031	26,791
9	Smith Ellis, *Brown*	1926	450	2,300,058	46,457
10	Stover, *Brown*	1926	1,500	7,158,872	152,409
11	Other fields, *Brown*		5,595	2,508,009	75,240
12	Total, *Brown*		12,265	29,814,300	567,460
13	Baum, *Callahan*	1925	500	872,368	7,714
14	Hatchett, *Callahan*	1927	375	1,385,980	44,486
15	Isenhour, *Callahan*	1923	600	2,178,644	45,299
16	Moutray, *Callahan*	1926	400	2,500,533	77,555
17	Other fields, *Callahan*		9,515	7,197,163	226,315
18	Total, *Callahan*		11,390	14,134,688	401,369
19	Burkett (Shallow), *Coleman*	1924	850	2,319,904	61,949
20	Burkett (Deep), *Coleman*	1930	200	688,698	12,020
21	Dibrell, *Coleman*	1927	170	419,003	37,636
22	Eastland, *Coleman*	1928	270	2,034,888	36,070
23	Jennings, *Coleman*	1927	135	470,981	9,931
24	Overall, *Coleman*	1926	200	1,253,982	14,304
25	Santa Anna, *Coleman*	1922	150	459,512	5,178
26	Stewardson, *Coleman*	1930	200	411,926	8,770
27	Other fields, *Coleman*		985	1,991,475	171,253
28	Total, *Coleman*			10,050,279	357,111
29	Other fields, *Comanche*		950	1,485,272	69,713
30	Desdemona, Eastland, Erath, *Comanche*	1918	6,175	23,138,773	153,482
31	Hillburn, *Eastland*	1919	400	1,111,128	9,025
32	Mangum, *Eastland*	1922	300	877,290	29,409
33	Pioneer, *Eastland*	1919	1,400	5,507,429	65,222
34	Other fields, *Eastland*			66,171,484	738,648
35	Total, *Eastland*			73,667,331	842,304
36	Howard, *Fisher*	1934	40	80,298	11,967
37	Royston, *Fisher*	1928	2,800	10,188,308	650,685
38	Rotan, (Robinson), *Fisher*	1936	640	858,242	365,520
39	Rotan, Bennett, *Fisher*	1937	80	35,684	18,059
40	Total, *Fisher*			11,162,532	1,046,231
41	Sandy Ridge (Higgs), *Jones*	1935	450	273,727	36,307
42	Dorsey-King (Hawley), *Jones*	1935	600	2,893,354	180,896
43	Jennings, *Jones*	1934	160	560,602	55,182
44	Noodle Creek, *Jones*	1927	1,030	6,688,860	194,829
45	Guitar (Hawley), *Jones*	1936	400	680,320	115,066
46	Sayles, *Jones*	1932	640	1,402,386	413,776
47	Avoca-Olander, *Jones*	1936	640	933,121	524,106
48	Avoca-Griffin, *Jones*	1938	640	614,541	610,001
49	Lewis, *Jones*	1936	800	661,820	415,802
50	Steffens, *Jones*	1937	640	134,390	113,124
51	Irvin, Noodle Creek, *Jones*	1937	500	132,583	95,870
52	Other fields, *Jones*			236,079	113,713
53	Total, *Jones*		6,500	15,211,783	2,868,672
54	Haskell County, total			161,016	28,635
55	Nolan County, total	1939	40		1,406
56	Cook, *Shackelford*	1925	1,460	15,876,208	663,171
57	Frye, *Shackelford*	1925	115	321,632	10,093
58	Hope, *Shackelford*	1923	220	1,257,842	38,790
59	Ibex, *Shackelford*	1921	1,240	2,437,858	25,914
60	Bluff Creek, *Shackelford*	1930	940	3,056,348	337,832
61	Newell, *Shackelford*	1925	640	821,719	51,119
62	Simmons-Harvey, *Shackelford*	1925	160	372,923	38,145
63	Tannehill-Matthews, *Shackelford*	1927	300	2,321,449	93,000
64	Ivy, *Shackelford*	1937	700	544,721	397,045
65	Other fields, *Shackelford*			10,915,345	520,219
66	Total, *Shackelford*		5,775	37,926,045	2,175,328
67	Stephens County, total			126,282,940	1,204,227
68	Stonewall County, total			50,488	37,906
69	Taylor County, total			346,713	77,206
70	Throckmorton County, total			3,290,774	102,863

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells, End of 1939	Character of Oil, Gravity A.P.I. at 60°F., Weighted Average	Producing Formation				
	Producing Oil[c]		Name	Age[e]	Character[f]	Depth, Avg. Ft. Top Prod. Zone	Structure[h]
1	11	38	Fry sand	Pen	S	1,150	ML, N
2	24	39	Fry sand	Pen	S	1,300	ML, N
3	10	37	Bend	Pen	L	2,450	A
4	112	35	Childress sand	Pen	S	800	ML, N
5	36	42	Fry sand	Pen	S	1,150	ML, N
6	149	40	Cross Cut sand	Pen	S	1,200	ML, N
7	100	42	Fry sand	Pen	S	1,300	ML, N
8	30	39	Fry sand	Pen	S	1,300	ML, N
9	37	41	Fry sand	Pen	S	1,300	ML, N
10	159	41	Blake sand	Pen	S	1,200	ML, N
11							
12							
13	15	39	Cross Plains	Pen	S	1,700	ML, N
14	94	38	Moutray	Pen	S	400	ML, N
15	136	37	Isenhour	Pen	S	700	ML, N
16	77	37	Moutray	Pen	S	750	ML, N
17	980						
18	1,302						
19	173	34	Burkett	Pen	S	400	M, L
20	19	41	Cross Cut	Pen	S	1,550	ML, N
21	14	42	Gwinnup	Pen	S	1,900	ML, N
22	28	42	Gwinnup	Pen	S	2,000	ML, N
23	26	39	Fry	Pen	S	1,950	ML, N
24	12	42	Strawn	Pen	S	2,300	A
25	10	39	Fry	Pen	S	1,500	ML. N
26	15	39	Fry	Pen	S	1,450	ML. N
27	50						
28							
29	138						
30	66		Desdemona	Pen	S	2,750	A
31	3	37	Bend	Pen	L	3,100	MN
32	35	38	Strawn	Pen	S	1,200	N
33	50	41	Caddo	Pen	L	2,450	AF
34	359						
35	651						
36	2	36		Pen	L	3,670	A
37	117	39	Saddle Creek	Pen	L	3,100	A
38	35	38	Camp Colorado	Pen	L	3,500	MN
39	1	39	Camp Colorado	Pen	L	3,600	MN
40	155						
41	21	37	Bluff Creek	Pen	S	1,900	N
42	79	39	6 Cisco sands	Pen	S	1,900–2,300	A
43	18	39	King	Pen	S	2,040	A
44	83	38	Camp Colorado	Pen	S	2,500	MCA
45	67	37	Cook	Pen	L	2,000	A
46	50	41	Cook	Pen	S	1,950	N
47	54	39	Strawn-Canyon	Pen	L	3,200	A
48	64	39	Strawn-Canyon	Pen	L	3,200	N
49	87	39	Bluff Creek	Pen	S	1,900	ML, N
50	30	37	Bluff Creek	Pen	S	1,900	ML, N
51	10	39	Swastika	Pen	S	2,900	A
52	27						
53	590						
54	10						
55	1	43	Strawn-Canyon	Pen	S	5,130	N
56	327	37	Cook sand	Pen	S	1,300	ML, N
57	38	35	Fry sand	Pen	S	450	ML, N
58	39	37	Hope sand	Pen	S	1,500	ML, N
59	17	39	Caddo	Pen	L	3,500	N
60	214	37	Bluff Creek	Pen	S	1,600	N
61	85	37	Tannehill sand	Pen	S	1,100	ML, N
62	19	39	Bluff Creek	Pen	S	1,700	N
63	84	38	Tannehill sand	Pen	S	1,150	ML, N
64	72	39	King sand Strawn-Canyon	Pen	S, L	1,900 3,200	A
65	1,082						
66	1,977						
67	691						
68	2						
69	22						
70	150						

[c] Footnotes to column heads and explanation of symbols are given on page 239.

was completed for a small producer from Strawn sand encountered at 5137 ft., after considerable mechanical difficulties. The Plymouth Oil Company's No. 1 McClure, sec. 49, block 23, T. and P.R.R. Co. survey, drilled through the Ellenburger limestone (Ordovician) and into the Hickory sandstone, Cambrian, with a total depth of 7453 ft., where it was abandoned as a dry hole.

Oil and Gas Development in the Texas Panhandle for the Year 1939

BY HENRY ROGATZ* AND H. W. McCUE†

(New York Meeting, February 1940)

Oil.—During the year 1939, there were 365 oil wells drilled in the Texas Panhandle, with a total daily initial production of 130,968 bbl.—that is, 69 fewer oil wells drilled than in the previous year, with a decrease in total daily initial production of 61,738 bbl. The total daily potential of the field on Dec. 5, 1939, as determined by the Texas Railroad Commission, was 1,344,677 bbl., an increase of 94,032 bbl. over the previous year. On Dec. 5, 1939, a daily allowable of 130,527 bbl., which was an

TABLE 1.—*Oil and Gas Production in the Texas Panhandle*

Line Number	County	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Carson	1921	19,570	247,194	32,470,051	2,534,788
2	Gray	1925	58,845	227,127	159,410.160	11,244,812
3	Hansford	1937		[1]	0	0
4	Hartley	1928		29,491	0	0
5	Hutchinson	1922	60,993	217,071	136,368,867	7,860,266
6	Moore	1926	640	432,130	4,708,468	432,709
7	Potter	1919	0	144,786	33,822	0
8	Sherman	1938	0	[1]	0	0
9	Wheeler	1925	8,250	153,768	16,972,520	2,267,936
10	Total		148,298	1,451,567	349,963,888	24,340,511

[b] Footnotes to column heads and explanation of symbols are given on page 239.
[1] Acreage not definite. For provisional figures, see paragraph on new developments, in text.

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† Columbian Fuel Corporation, Amarillo, Texas.

increase of 58 per cent over 1938, was assigned to the field to be produced from 4239 wells. The total amount of oil produced for the year was 24,340,511 bbl., making a cumulative total of 352,172,138 bbl. during the last 18 years. No new oil-producing acreage was discovered.

Gas.—During the year, 86 gas wells were drilled, having a combined open flow of 2,162,000,000 cu. ft.; that is, 17 less than the number of wells drilled in 1938, with a decrease in the open flow of 1,004,300 cu. ft. per day. The gas production for the year was 634 billion cu. ft., and the total gas taken over the past life of the field was, approximately, 8¾ trillion cu. ft. A resurvey of the gas acreages and rock pressures divided into areas of sweet and sour gas showed the figures given in Table 2.

Pipe-line Gas.—The pipe-line companies withdrew 248,908,072,000 cu. ft. of gas (a daily average of 681,939,000 cu. ft.). The total yearly withdrawals by pipe line increased 18,600,218,000 ft. from those of 1938.

Natural Gasoline.—Throughout the greater part of the year, 42 gasoline-extraction plants processed 1,439,288,000 cu. ft. per day, a total of 525,340,324,000 cu. ft. for the year. This gas yielded 295,071,798 gal. of natural gasoline. The total daily capacity of all the plants is 2,467,500 thousand cubic feet.

Carbon Black.—Thirty-one carbon-black plants operated during 1939, burning 290,305,931 thousand cu. ft., or a daily amount of 795,358,000 cu. ft., and producing approximately 420,000,000 lb. of carbon black.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at 60° F. Weighted Average	Sulphur, Per Cent
1			850	69	3	*y*	473	321	*y*	*y*	430	337.6		39	0.06
2			2,407	149	16	*y*	1,991	225	*y*	*y*	430	318.7		39	0.04
3			1	0	0	*y*	0	0	0	0	430	430.0			
4			4	0	0	*y*	0	4	0	0	430	422.1			
5			2,442	166	36	*y*	1,446	336	*y*	*y*	430	289.8		35	0.08
6			381	41	0	*y*	0	340	*y*	*y*	430	382.6		31	0.08
7			54	3	0	*y*	0	44	0	0	430	402.0		*y*	*y*
8			3	1	0	*y*	0	0	0	0	430	430.0			
9			747	22	12	*y*	329	342	*y*	*y*	430	265.9		37	0.04
10	8,079,544	634,000	6,889	451	67	*y*	4,239	1,612	*y*	*y*	430	341.4			

Refineries.—Runs to the eight operating refineries for the year 1939 amounted to 14,381,000 bbl.; a daily average of 39,400 bbl., or an increase of 2737 bbl. per day over 1938. At the end of the year only six refineries were operating, two having been shut down in September and November.

Storage.—The oil in storage decreased 3,023,000 bbl.; that is, from 5,601,000 to 2,578,597 bbl. The two weeks shutdown during the late summer were responsible for most of this reduction, which cut the total storage to the lowest figure in the field's history. The total storage capacity at the end of the year was 15,691,500 barrels.

New Developments.—No new oil-producing areas were discovered during 1939 and no additional oil acreage was proven. The gas trend connecting the Panhandle and Hugoton (Kansas) gas fields had one new gas discovery, which was important because of its aid in establishing the existence of this connecting trend. The latter lies in eastern Sherman, western Hansford Counties, Texas, and in the central part of Texas County, Oklahoma, and has never been included in the proven gas acreage tabulation, because of the indefinite boundary lines. A rough estimate of 78,000 acres in western Hansford County, 135,000 acres in eastern Sherman County, Texas, and 260,000 acres in Texas County, Oklahoma, is considered conservative—a total of 473,000 acres. The ITIO structure, in western Sherman County, which was tested last year,

TABLE 1.—(*Continued*)

	Producing Formation								Deepest Zone Tested to End of 1939	
Line Number	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.[2]		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Big Lime series (Wichita) Granite Wash (Cisco?)	Permo-Pen Pen	D, DA LA GW	*x*	3,000	3,040	40	AF	Granite wash (E zone)	*y*
2	Big Lime series (Wichita) Granite Wash (Cisco?)	Permo-Pen Pen	D, DA LA GW	*x*	3,100, 2,850	3,150, 2,880	50, 30	AF	Granite wash (E zone)	*y*
3	Big Lime series (Wichita)	Permo-Pen	D, DA	*x*	*x*	*x*	*x*	AF	Big Lime series (Wichita)	3,311
4	Big Lime series (Wichita)	Permo-Pen	D, DA	*x*	*x*	*x*	*x*	AF	Big Lime series (Wichita)	*y*
5	Big Lime series (Wichita)	Permo-Pen	D, DA, L	*x*	2,800–3,200	2,840–3,240	40	AF	Arbuckle	5,333
6	Big Lime series (Wichita)	Permo-Pen	L	*x*	3,400	*x*	*x*	AF	Arbuckle	8,013
7	Granite wash (Cisco)	Permo-Pen	GW	*x*	*x*	*x*	*x*	AF	Granite wash (E zone)	*y*
8				*x*	*x*	*x*	*x*	AF	Big Lime Series (Permo-Pen)	*y*
9	Big Lime series (Wichita) Granite wash (Cisco)	Permo-Pen	D, GW	*x*	2,400	2,430	30	AF	Arbuckle	2,957
10										

[2] Depths refer to oil sands only.

may expand into an additional extensive gas area, but the real extent cannot even be estimated at present.

TABLE 2.—*Rock Pressures and Gas Acreage, Texas Panhandle*

County	Sweet		Sour		Average	
	R. P.	Acreage	R. P.	Acreage	R. P.	Acreage
Carson	350.0	225,259	209.9	21,935	337.6	247,194
Gray	326.4	214,777	185.0	12,350	318.7	227,127
Hartley	421.0	2,043	422.2	27,448	422.1	29,491
Hutchinson	273.5	35,796	293.0	181,275	289.8	217,071
Moore	381.4	257,295	384.4	174,835	382.6	432,130
Potter	402.0	144,786			402.0	144,786
Wheeler	265.9	153,768			265.9	153,768
Total	345.2	1,033,724	332.2	417,848	341.4	1,451,567

Wildcats.—Nine wildcats were completed, none of which discovered oil or gas in commercial quantities. They were distributed as follows: Armstrong County, 1; Collingsworth, 2; Cottle, 1; Lipscomb, 1; Roberts, 3. The total footage drilled was 40,025 feet.

Oil and Gas Development in South Texas during 1939

By Michel T. Halbouty,* Member A.I.M.E.

South Texas, one of the world's important oil and gas-producing areas, continued to hold interest during 1939 as another series of new fields and new producing levels was developed within its boundaries at a fairly continuous rate throughout the year. There were 1801 wells drilled in this area in 1939, compared to 1678 in 1938; of these, 1515 were drilled in established fields, or as extensions to proven areas (semi-wildcat), and 286 were drilled as *rank* wildcats, in search of new production. Among these rank wildcats, 22 produced oil, 7 produced distillate and gas and 257 were abandoned as dry holes (see Table 5). Of the 1515 field and extension wells, 1213 produced oil, or distillate and gas, 50 produced only gas and 252 were dry; 38 found new productive sand levels in proven fields. Jim Wells County led this district in discoveries, having had 9 new fields and 9 new productive sands found within its border during 1939. Most active of the 1939 discoveries were Reynolds and Ben Bolt fields in Jim Wells County and Minnie Bock field in Nueces County; among producing fields the most active were: East White Point and Aransas Pass (McCampbell). Production from South Texas in 1939 totaled 55,105,506 bbl. against a total of 56,152,122 bbl. produced in 1938.

South Texas should continue its present rate of development and exploration and this should result in the discovery of many fields in its numerous oil-bearing zones, and should also lead to more knowledge of the possibilities of its deeper horizons, such as the Mt. Selman and Wilcox formations; with the latter holding particular interest at the present time. Tide Water Associated Oil Company's A. M. Bruni No. 1, Cole-Bruni field, Webb County, the deepest well drilled along the Mirando trend, was carried to 8959 ft., where it started to blow out from a Wilcox sand topped at 8954 ft., making gas, distillate and mud under heavy pressure. After the well was killed, drill stem became stuck and was cemented in place in order to test a Queen City (Mt. Selman) sand logged from 5620 to 5675 ft. This and other shows found in other wells along this trend, but out of this district, have served to increase the importance of this but little explored Sparta-Wilcox trend of South Texas during the year, and more activity along it is to be expected in the near future.

Summarized at meeting; manuscript received at the office of the Institute March 18, 1940.

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Complete reference to the nomenclature of formations, producing horizons, trends and other general geological and engineering information for this district is contained in Volume 127 and Volume 132 of the TRANSACTIONS.

RECYCLING IN THE SOUTH TEXAS DISTRICT

The number of distillate-producing areas in South Texas has steadily increased, therefore the number of recycling plants operating or being planned has increased. To some extent this has been a result of an order by the Texas Railroad Commission, which required shutting in all wells wastefully blowing gas into the air. This order has prevented the use of regular separator methods in the production of distillate with excessive gas-oil ratios. Intended to conserve the gas resources of the state, this order necessitates recycling operations, by means of which pressure in the producing zones can be maintained and recoverable distillate reserves are greatly increased. With recycling operations, a relatively small number of wells is needed to drain a distillate-producing area, which is a saving to the operators, and areas formerly considered nonprofitable because of their extremely high gas and low oil content are now attracting the industry's attention because of the larger and more economical production made possible through recycling.

Clear or water-white distillate is believed by many authorities to exist as a vapor while in the underground reservoir; the heavier portions of this vapor are thought to condense into a liquid if pressure within the reservoir is reduced, as when distillate is produced without returning the dry residue gas to the producing zone. This *reservoir* condensation, considered to take place by means of *retrograde* pressure (a liquefaction of gases by pressure reduction at constant temperature), becomes only thinly diffused throughout the producing sand, creating a saturation too low to cause fluid movement to the well bore, and it becomes unrecoverable. By returning dry residue gas to the producing zone, reservoir pressure may be maintained, retrograde pressure condensation within the reservoir may be prevented and/or delayed, and a greater production of distillate may ultimately be obtained.

Condensation of these gases on the surface is accomplished through normal temperature condensation in the well and in artificial cooling processes, where temperature reductions lower the kinetic energy of the gas molecules, causing liquefaction, and/or by retrograde pressure condensation. Since this pressure reduction results in a like temperature drop, liquefaction is brought about by both retrograde pressure and more normal temperature condensation. Thus distillate is obtained when conditions of temperature and/or pressure in the well, or in the surface processing systems, become lower than those originally exerted on the distillate-bearing gases when in the reservoir.

It becomes a necessity, then, to return all possible residue gas to the formation, since the net loss of recoverable distillate in the producing sand, due to retrograde pressure condensation, is dependent on the extensiveness of the pressure decline. The injection of residue gas back into the formation is being carried on through the location of input wells on the flanks of structures or on top of structures. The problems presented by different fields probably will result in a variety of arrangements; the question of which arrangement is best seems not to have been determined, since recycling, already of great importance to South Texas, is relatively a new development in the petroleum industry.

Field Discoveries in 1939 *with the Trend in Which Each Is Located*

Field	County	Trend	Type of Production to Date	Field	County	Trend	Type of Production to Date
Adami	Webb	Mirando	Oil	Minnie Bock	Nueces	Frio	Oil
West Alfred	Jim Wells	Vicksburg	Oil	South Mirando Valley	Zapata	Mirando	Oil
Ben Bolt	Jim Wells	Vicksburg	Oil				
Blucher	Jim Wells	Vicksburg	Distillate and gas	Muralla	Duval	Benavides (Pettus sand)	Oil
Camada	Jim Wells	Vicksburg (Hockleyensis sand)	Oil	Odem	San Patricio	Frio	Distillate and gas
North Casa Blanca	Duval	Mirando	Oil	Reynolds	Jim Wells	Vicksburg (Frio sand)	Oil
Chiltipin	Duval	Benavides (Pettus sand)	Oil	North Ricaby	Starr	Mirando	Oil
Clark-Muil	Jim Wells	Vicksburg (Frio sand)	Oil, distillate and gas	North Rincon	Starr	Vicksburg	Oil
				Robston	Nueces	Frio	Oil
Holland-Hebbronville	Jim Hogg	Mirando	Oil	Seabury	Starr	Mirando	Oil
				Sejita	Duval	Benavides (Hockleyensis sand)	Distillate and gas
LaGloria	Jim Wells	Vicksburg (Frio sand)	Oil, distillate and gas				
South LaReforma	Starr	Vicksburg (Frio sand)	Distillate and gas	Southland	Duval	Benavides (Pettus sand)	Oil
North Luby	Nueces	Frio	Oil	Sullivan City	Hidalgo	Mirando	Oil
Magnolia City	Jim Wells	Vicksburg (Frio sand)	Oil	Tarancahuas	Duval	Mirando	Oil
				Volpe	Webb	Mirando	Oil
East Mathis	San Patricio	Vicksburg (Frio sand)	Oil	Wade City	Jim Wells	Vicksburg (Frio sand)	Distillate and gas

During the year 1939 there were two recycling plants in operation in the South Texas area, in the Agua Dulce field, Nueces County, South Corpus Christi district. The plants at Agua Dulce are recycling 260,000,000 cu. ft. of gas per day and the average recovery of condensate is 25 bbl. per 1,000,000 cu. ft.; that is, 6500 bbl. of distillate per day are marketed from these two plants. Recycling plants are under construction or contracts have been let for construction at Agua Dulce, Nueces County; East Alice, Jim Wells County; and LaBlanca, Hidalgo County, all in the South Corpus Christi district and all scheduled for operation during 1940. These three plants will have a capacity of 500,000,000 cu.

TABLE 1.—*Oil and Gas Production in South Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Adami, *Webb*	1939	190	0	12,852	12,852
2	Agua Dulce, *Nueces*	1928	150	9,500[2]	660,078	151,598
3	North Agua Dulce, *Neuces*	1938	50	250[3]	59,538	49,286
4	Albercas, *Webb*	1927	250	200	2,500,071	16,925
5	Alfred,[1] *Jim Wells*	1938	140	0	87,753	57,064
6	Alice, *Jim Wells*	1938	1,280	400[3]	1,399,318	925,349
7	East Alice (Tom Graham), *Jim Wells*	1938	680	360[3]	330,383	330,383
8	Alta Mesa, *Brooks*	1926	420	180	484,059	141,894
9	Alta Verde, *Brooks*	1936	100	60	30,076	7,076
10	Alworth, *Jim Hogg*	1926	80	570	27,793	0
11	Andrews, *Zapata*	1924	0	2,000	Gas	0
12	Angelita, *San Patricio*	1934	60	0	36,056	4,349
13	Aransas (gas), *San Patricio*	1931	0	760	Gas	Gas
14	Aransas Pass (McCampbell), *San Patricio, Aransas*	1936	2,800	400	5,615,968	2,796,987
15	Armagosa, *Jim Wells*	1931	0	400	Gas	Gas
16	Aviator, *Webb*	1922	955	320	5,881,486	107,666
17	Baldwin, *Neuces*	1935	270	40	679,778	112,054
18	Bandera, *Jim Wells*	1938	0	40[3]	1,499	1,499
19	Barbacoas,[6] *Starr*	1933	80	580	33,374	1,908
20	Benavides (North Sweden), *Duval*	1937	5,900	200	7,155,895	2,866,661
21	Ben Bolt, *Jim Wells*	1939	840	40	98,102	98,102
22	Bird Island, *Kleburg*	1938	40	40[3]	8,366	8,366
23	Blas Uribe, *Zapata*	1934	0	80	Gas	0

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[b] Footnotes to column heads and explanation of symbols are given on page 239.
[1] Includes West Alfred.
[2] Gas, or distillate and gas.
[3] Distillate and gas.
[6] Includes North Barbacoas.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.
			During 1939		End of 1939			Number of Wells[5]		
	During 1939[4]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[6]	Producing Gas[6]	Flowing Crude	Artificial Lift	Initial
1	0	19	19	0	0	19	0	5	14	
2	31,352.2	89	28	2	21	2	15[2]	1	1	800 1,650 1,800 2,000 2,500 2,000
3	Included in Agua Dulce	7	5	0	1	1	5[3]	1	0	1,820 1,750
4	0	100	0	10	5	17	0	1	16	600
5	0	7	4	0	1	6	0	4	2	125 835
6	939.6	74	15	0	13	58	3	58	0	1,350 750 1,900 900 1,200
7	633.2	43	39	0	7	34	2	34	0	1,350 800 1,500 1,200
8	73.1	30	0	0	3	22	2	1	21	500 500 175 575
9	0	6	0	0	0	2	0	0	2	100
10	0	16	0	0	0	0	0	0	0	
11	0	12	0	0	4	0	0			
12	0	3	1	0	1	1	0	0	1	1,550 Pump
13	1,892.1	19	0	0	12	0	7			1,480
14	570.1	292	142	0	43	244	5	223	21	2,250 2,200 2,700 2,500 2,300
15	293.8	6	0	0	1	0	5			
16	0	216	0	2	10	75	0	0	75	
17	105.7	9	0	0	0	8	1	0	8	225
18	39.8	1	0	0	0	0	1[3]			3,550
19	0	13	0	0	1	2	0	1	1	2,200
20	392.2	274	22	0	22	249	3	209	40	1,600 925 460 750 400 190
21	49.4	24	24	0	0	22	1	22	0	875 2,100 200
22	23.1	2	1	0	1	1	0	1	0	2,700
23	0	3	0	1	0	0	0			

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[4] Gas production figures are totals through November, 1939.
[5] Does not include distillate producers.

TABLE 1.—(*Continued*)

Line Number	Representing Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
		Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
1		20.5–21.5	Mirando	Eoc	S	Por	975	1,000	7	ML	Mirando	1,012
2	PM	Gas	Catahoula	Olig	S		1,998	2,400	10		Yegua	13,728
		55	Frio	Olig	S	30	4,650	4,675	9	DF		
		56–59	Frio	Olig	S		4,800	4,900	15			
		37.5–58	Frio	Olig	S		5,295	5,307	10			
		56	Frio	Olig	S		5,575	5,700	15			
		55–60	Frio	Olig	S		6,615	6,845	15			
		60	Frio	Olig	S		6,932	6,938	6			
3		48.2	Frio	Olig	S	30	4,810	4,834	15	DF	Jackson	8,706
		56	Frio	Olig	S		5,081	5,088	7			
		48	Frio	Olig	S		5,575	5,593	18			
4		21	Cole	Eoc	S	Por	2,125	2,175	17	MF	Yegua	3,710
5		47	Frio	Olig	S	30–35	3,223	3,234	11	MF	Jackson	5,774
		45.2	Vicksburg	Olig	S		4,660	4,675	13			
6		42	Frio	Olig	S	28.7	3,480	3,600	16	A	Cockfield	7,335
		38.5–43	Frio	Olig	S	Por	4,788	4,800	11			
		44	Frio	Olig	S	Por	5,030	5,161	12			
		44	Frio	Olig	S	Por	5,211	5,223	12			
		44	Vicksburg	Olig	S	Por	5,350	5,375	20			
		45	Vicksburg	Olig	S	Por	5,450	5,500	20			
7		38	Frio	Olig	S	28.7	3,480	3,496	15	A	Vicksburg	5,760
		54	Frio	Olig	S	Por	4,675	4,700	10			
		56	Frio	Olig	S	Por	5,125	5,175	12			
		42–56	Vicksburg	Olig	S	Por	5,300	5,400	18			
8		Gas	Oakville	Mio	S	Por	1,100	1,140	20	D	Jackson	8,022
		24	Catahoula	Olig	S	Por	2,450	2,485	12			
		24	Catahoula	Olig	S	Por	3,000	3,025	10			
		25	Catahoula	Olig	S	Por	3,550	3,585	20			
9		21.5	Caprock	Mio	S	Por	916	926	10	DS	Yegua	5,096
10		21	Upper Jackson	Eoc	S	Por	1,020	1,030	6	ML	Jackson	2,199
11		Gas	McElroy	Eoc	S	Por	1,510	1,515	5	MF	Yegua	2,312
12		38	Frio	Olig	S	Por	5,370	5,382	10	Nf	Frio	7,131
		36	Frio	Olig	S	Por	6,225	6,235	10			
13		Gas	Catahoula	Olig	S	Por	3,653	3,663	10	D	Frio	6,026
14		40.5	Marginulina	Olig	S	25–34	6,539	6,554	15	AF	Frio	9,074
		46	Frio	Olig	S		6,780	6,888	15			
		39.5	Frio	Olig	S		7,080	7,180	18			
		42	Frio	Olig	S		7,200	7,270	15			
		58	Frio	Olig	S		7,345	7,419	15			
15		Gas	Discorbis-Het.	Olig	S	Por	2,170	2,200	10	D	Yegua	6,315
16		21	Mirando	Eoc	S	Por	1,525	1,660	11	MF	Cook Mt.	3,975
17		Gas	Oakville	Mio	S	Por	3,230	3,250	12	AF	Frio	6,610
		25.8	Catahoula	Olig	S	Por	3,874	3,880	6			
		24.8	Catahoula	Olig	S	Por	4,050	4,074	12			
18		Gas	Jackson	Eoc	S	Por	6,408	6,416	8	AF	Yegua	8,302
19		Gas	Catahoula	Olig	S	Por	685	715	10	DF	Yegua	6,567
		Gas.24.8–27	Frio	Olig	S	Por	2,450	2,950	15			
		58	Cockfield	Eoc	S	Por	5,376	5,398	22			
20		43	Cole	Eoc	S	Por	3,840	3,975	22	AF	Yegua	6,510
		43	Chernosky	Eoc	S	Por	4,357	4,552	15			
		43	Upper Govt. Wells	Eoc	S	Por	4,730	4,755	20			
		43.6	Lower Govt. Wells	Eoc	S	Por	4,755	4,830	25			
		44.7	Pettus	Eoc	S	Por	5,310	5,382	22			
		45	Cockfield	Eoc	S	Por	5,486	5,518	17			
21		41.5	Vicksburg	Olig	S	Por	5,181	5,272	15	A	Vicksburg	5,480
		Gas	Vicksburg	Olig	S	Por	5,370	5,390	15			
		42.5	Vicksburg	Olig	S	Por	5,413	5,433	15			
22		44	Frio	Olig	S	Por	7,200	7,310	80	AF	Frio	9,636
23		Gas	Jackson	Eoc	S	Por	1,825	1,840	15	ML	Yegua	3,000

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
24	Blucher, *Jim Wells*	1939	0	40[3]	Distillate	Distillate
25	Calliham,[7] *McMullen*	1918	500	730	821,426	60,134
26	Camada, *Jim Wells*	1939	40	0	2,290	2,290
27	Campana, *McMullen*	1938	10	0	Spray with gas	0
28	Captain Lucey, *Jim Wells*	1932	120	520	447,420	42,181
29	Carolina—Texas, *Webb*	1921	110	1,460	260,947	3,836
30	Casa Blanca, *Duval*	1938	340	100	234,171	157,798
31	North Casa Blanca, *Duval*	1939	100	0	26,845	26,845
32	Cedro Hill, *Duval*	1938	200	40	50,795	50,324
33	Chapman Ranch, *Nueces*	1937	50	40	42,782	1,372
34	Charamousca,[9] *Duval*	1935	210	0	323,777	134,284
35	Charco Redondo, *Zapata*	1913	570	60	185,164	1,464
36	Chiltipin, *Duval*	1939	40	20	4,621	4,621
37	Clara Driscoll, *Nueces*	1935	720	260	1,695,015	722,616
38	South Clara Driscoll, *Nueces*	1937	360	40	411,652	249,547
39	Clark-Muil, *Jim Wells*	1939	100	80	18,043	18,043
40	Clopton-Green, *Starr*	1937	0	10	Gas	0
	Cole Group, *Duval, Webb*					
41	Gas	1924	0	7,000	Gas	Gas
42	O'Hern[10]	1927	2,300	2,200	8,472,365	1,821,451
43	West	1927	500	1,000	4,217,937	126,970
44	Bruni[11]	1934	880	160	2,677,047	194,619
45	Colmena, *Duval*	1934	240	400	329,934	82,126
46	Colorado, *Jim Hogg*	1936	360	0	199,442	122,028
47	Comitas (Haynes), *Zapata*	1934	750	40	1,299,358	251,054
48	Conoco Driscoll, *Duval*	1924	640	980	2,089,152	646,629
49	Corpus Christi (Saxet Heights), *Nueces*	1935	1,500	160	6,520,225	470,111
50	Crowther, *McMullen*	1915	80	0	25,000	0
51	Cuellar, *Zapata*	1927	340	220	2,565,193	35,264

[7] Includes South Calliham.
[9] Includes S.R.C.
[10] Includes Cole Middle
[11] Includes East Bruni.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.
			During 1939		End of 1939			Number of Wells[5]		
	During 1939[4]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[6]	Producing Gas[6]	Flowing Crude	Artificial Lift	Initial
24	83.8	1	1	0	0	0	1[3]			3,600
25	23.7	137	5	2	12	58	2	0	58	
26	0	2	2	0	1	1	0	1	0	850
27	0	1	0	0	1	0	0	0	0	140
28	909.2	17	0	0	0	5	12	3	2	1,100 200 725
29	658.7	65	1	2	10	2	9	0	2	
30	34.4	38	9	0	5	31	2	0	31	Pump
31	0	9	9	0	0	9	0	1	8	
32	3.0	22	21	0	0	21	1	7	14	
33	341.0	2	0	0	1	0	1			550 625
34	0	21	0	2	4	15	0	0	15	75
35	0	328	1	3	12	52	0	0	52	
36	0	3	3	0	1	2	0	2	0	1,440
37	532.9	73	29	0	13	58	2	44	14	400 2,150
38	33.2	29	10	0	1	27	1	23	4	450 200
39	92.3	7	7	0	1	5	1	5	0	1,400 900
40	0	1	0	0	0	0	0			425
41	2,468.2	105	0	0	27	0	58			
42	2,314.3	273	1	0	24	230	17	3	227	
43	43.4	119	5	1	15	60	6	2	58	
44	128.3	60	0	0	12	38	2	15	23	900
45	183.0	36	0	1	5	25	1	1	24	525
46	0	19	15	0	2	17	0	6	11	65
47	0.6	191	15	2	7	162	0	0	162	
48	183.9	64	13	1	8	36	4	30	6	
49	335.7	251	0	19	40	85	1	60	25	1,650 825
50	0	23	0	0	0	0	0	0	0	
51	517.6	86	0	0	6	24	2	0	24	385

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
		Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
24		54	Vicksburg	Olig	S	Por	7,500	7,560	20	A	Vicksburg	8,004
25		20	Cole-Hock.[8]	Eoc	S	Por	780	876	28	MF	Carrizo	5,301
		20.6	Govt. Wells-Pettus[8]	Eoc	S	Por	1,030	1,060	10			
		Gas	Loma Novia	Eoc	S	Por	1,230	1,236	6			
26		46.4	Hockleyensis	Eoc	S	Por	5,627	5,637	10	ML	Yegua	7,041
27		22	Govt. Wells	Eoc	S	Por	2,492	2,517	20	MF	Pettus	3,102
28		Gas	Discorbis-Het.	Olig	S	Por	3,893	4,000	6	AF	Vicksburg	6,500
		39.6	Frio	Olig	S	Por	5,350	5,370	20			
		42	Vicksburg	Olig	S	Por	5,679	5,685	7			
29		Gas	Cole	Eoc	S	Por	1,270	1,280	10	DF	Mt. Selman	5,474
		Gas	McElroy	Eoc	S	Por	1,800	2,200	65			
		34	Cockfield	Eoc	S	Por	2,597	2,615	10			
		46	Yegua	Eoc	S	Por	2,947	3,198	50			
		42	Queen City	Eoc	S	Por	4,996	5,056	60			
30		20	Cole	Eoc	S	Por	1,180	1,190	10	ML	Jackson	2,133
31		20	Cole	Eoc	S	Por	1,030	1,059	9	ML	Jackson	1,788
32		20	Cole	Eoc	S	Por	1,436	1,476	10	ML	Jackson	2,530
33		40.8	Catahoula	Olig	S	Por	5,046	5,058	12	ML	Frio	7,012
		41.8	Frio	Olig	S	Por	6,464	6,484	20			
34		20	Upper Hock.	Eoc	S	Por	1,094	1,101	7	MF	Cook Mt.	3,892
		20.3	Mirando	Eoc	S	Por	1,525	1,550	10			
35		17	Frio	Olig	S	Por	150	200	8	ML	Yegua	3,000
		Gas	Jackson	Eoc	S	Por	989	995	5			
36		46	Pettus	Eoc	S	Por	4,760	4,795	10	MF	Pettus	4,860
37		23.5–27.8	Catahoula-Het.	Olig	S	Por	3,807	3,980	12	Df	Vicksburg	8,194
		31.5	Frio	Olig	S	Por	4,650	4,690	10			
		37	Frio	Olig	S	Por	5,120	5,133	10			
		31–37	Frio	Olig	S	Por	5,265	5,433	15			
		42	Frio	Olig	S	Por	5,505	5,720	15			
38		23.6	Heterostegina	Olig	S	Por	3,917	3,930	12	Df	Vicksburg	7,560
		32	Frio	Olig	S	Por	4,648	4,748	10			
		36.5	Frio	Olig	S	Por	5,076	5,090	12			
		35	Frio	Olig	S	Por	5,255	5,477	15			
		40	Frio	Olig	S	Por	5,502	5,776	15			
		37	Frio	Olig	S	Por	6,556	6,566	10			
39		60	Frio	Olig	S	Por	4,795	4,835	20	N	Vicksburg	5,850
		42	Vicksburg	Olig	S	Por	5,326	5,330	4			
40		Gas	Cole	Eoc	S	Por	1,604	1,614	10	*x*	Cook Mt.	4,620
41		Gas	Frio	Olig	S	Por	500	515	10	A	Reklaw	6,394
		Gas	Cole	Eoc	S	Por	1,650	1,730	8			
42		Gas	Mirando	Eoc	S	Por	2,314	2,450	10	A	Queen City	5,057
		28.5	Caddell-Cockfield	Eoc	S	Por	2,750	2,945	15			
43		21.5	Mirando	Eoc	S	Por	2,335	2,346	11	A	Mt. Selman	5,225
		Gas	Cockfield	Eoc	S	Por	2,900	2,925	10			
44		36	Yegua	Eoc	S	Por	3,270	3,280	10	A	Wilcox	8,959
		41.7	Yegua	Eoc	S	Por	3,400	3,450	14			
45		20	Cole	Eoc	S	Por	1,486	1,553	19	ML	Yegua	3,396
46		47.4	Cockfield	Eoc	S	Por	3,006	3,041	8	ML	Yegua	3,202
47		21.4	McElroy	Eoc	S	Por	815	1,000	10	ML	Cook Mt.	3,502
48		22.5	Cole	Eoc	S	Por	2,448	2,470	20	A	Yegua	4,695
		23	Hockleyensis	Eoc	S	Por	2,884	2,900	6			
		32	Govt. Wells	Eoc	S	Por	3,370	3,448	10			
49		25	Catahoula	Olig	S	Por	4,076	4,096	8	A	Frio	7,531
		36.5	Heterostegina	Olig	S	Por	5,157	5,167	10			
50		18	Diboll	Eoc	S	Por	500	520	10	ML	*x*	*x*
51		Gas	McElroy	Eoc	S	Por	1,100	1,116	16	ML	Mt. Selman	4,532
		22	McElroy	Eoc	S	Por	1,325	1,350	10			

[8] In Calliham.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
52	Eagle Hill, *Duval*	1933	550	200	1,017,515	238,896
53	Edinburg, *Hidalgo*	1935	20	0	500	0
54	El Mesquite, *Duval*	1935	10	0	976	0
55	El Tanque (South Ricaby), *Starr*	1937	280	30	280,760	117,578
56	Escobas, *Zapata*	1929	3,330	340	8,371,887[12]	379,319
57	Ezzell, *McMullen*	1937	1,450	100	1,719,870	1,013,785
58	Fitzsimmons, *Duval*	1938	750	0	1,028,381	828,382
59	Flour Bluff, *Nueces*	1936	2,580	20	4,774,297	1,322,477
60	Government Wells, *Duval*	1928	7,500	600	41,679,512	3,322,624
61	Guerra (Cuevitas), *Starr*	1933	400	400	953,983	154,938
62	Hayden, *Starr*	1937	0	20	Gas	0
63	Henne-Winch-Farris, *Jim Hogg*	1924	720	440	3,211,027	1,978
64	Hoffman, *Duval*	1933	3,000	500	3,467,004	1,526,935
65	Holland-Hebbronville, *Jim Hogg*	1939	10	0	315	315
66	Jacob,[13] *McMullen*	1926	1,230	80	1,368,381	148,103
67	Jennings, *Zapata*	1914	400	1,700	See Escobas	294,660
68	Kelsey, *Jim Hogg, Brooks*	1938	840	40	316,271	308,414
69	Killam, *Webb*	1937	650	150	687,762	196,272
70	North Killam,[14] *Webb*	1938	80	20	32,161	32,161
71	Kingsville, *Kleburg*	1920	240	675	716,512	14,308
72	Kohler,[15] *Duval*	1926	360	5,000	765,299	138,941
73	Labbe, *Duval*	1934	200	500	234,899	68,667
74	LaBlanca, *Hidalgo*	1936	0	1,000[3]	384,317	110,068
75	La Gloria, *Jim Wells*	1939	40	200[3]	8,319	8,319
76	La Reforma, *Starr*	1938	0	100[3]	9,741	4,426
77	South La Reforma, *Starr*	1939	0	50[3]	Distillate	Distillate
78	Las Animas, *Jim Hogg*	1937	50	80	27,127	17,771
79	Las Vieja, *Willacy*	1936	40	0	17,954	0
80	Laurel, *Webb*	1932	220	320	682,425	4,746
81	Leaseholders, *Webb*	1922	10	20	25,000	0
82	Loma Alta, *McMullen*	1935	20	0	117,030	21,524

[12] This total includes production for Jennings field

[13] Includes North Jacob.

[14] Includes Houser.

[15] Includes North (Deep) Kohler

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.
			During 1939		End of 1939			Number of Wells[5]		
	During 1939[4]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing Crude	Artificial Lift	Initial
52	79.3	61	7	0	1	52	3	4	48	
53	0	1	0	0	1	0	0	0	0	
54	0	1	0	0	0	0	0	0	0	
55	0	20	5	1	4	15	0	3	12	200
56	0	400	14	5	14	279	0	0	279	
57	0	148	47	0	7	141	0	0	141	90 1,200
58	0	77	38	0	0	77	0	74	3	370
59	621.1	116	3	0	6	109	1	95	14	1,420
60	124.4	829	4	5	47	686	3	1	685	600
61	0.1	21	1	0	5	14	0	10	4	400
62	0	1	0	0	0	0	0	0	1	550
63	0	181	0	0	0	1	0			
64	207.2	330	69	0	21	298	5	107	191	890 475 200
65	0	1	1	0	0	1	0	0	1	Pump
66	0	127	0	3	5	79	0	0	79	
67	344.7	119	3	1	3	99	4	4	95	
68	115.3	52	49	0	0	51	1	51	0	1,170 1,050 225
69	0	92	9	2	10	74	0	0	74	
70	0	7	5	0	1	6	0	0	6	800
71	25.2	20	0	0	3	7	1	1	6	
72	1,840.5	91	1	0	14	14	25	3	11	320
73	343.4	29	0	1	8	14	4	6	8	890 260
74	3,106.2	10	1	0	3	0	7[3]			2,700 3,000 3,850
75	272.0	4	4	0	1	1	2[3]	1	0	2,000 3,150
76	173.7	2	0	0	1	0	1[3]			2,125
77	Gas	1	1	0	1	0	0			2,050
78	0	8	0	0	5	3	0	3	0	200
79	0	1	0	0	0	0	0	0	0	2,056
80	66.0	33	0	0	1	6	2	0	6	
81	0	3	0	0	0	0	0	0	0	235
82	0	4	0	0	0	3	0	0	3	

Table 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
		Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
52		22.5	Cole	Eoc	S	Por	1,450	1,540	20	MF	Cockfield	2,752
		23	Govt. Wells	Eoc	S	Por	2,120	2,150	20			
53		*y*	Frio	Olig	S	Por	6,685	6,770	20*y*	D	Frio	7,508
54		43	Cockfield	Eoc	S	Por	2,850	2,862	12	ML	Yegua	3,502
55		Gas	Catahoula	Olig	S	Por	425	429	4	ML	Frio	2,379
		31	Frio	Olig	S	Por	1,739	1,775	14			
		30	Frio	Olig	S	Por	1,866	1,879	6			
56		20	Jackson	Eoc	S	Por	1,020	1,050	6	MF	Cook Mt.	3,500
		21	Jackson	Eoc	S	Por	1,137	1,302	14			
		21	Jackson	Eoc	S	Por	1,450	1,600	7			
57		19.7	Loma Novia	Eoc	S	Por	1,490	1,550	11	ML	Cook Mt.	3,108
58		46	Hockleyensis	Eoc	S	Por	3,592	3,623	15	ML	Yegua	5,285
		47	Pettus	Eoc	S	24–28	4,260	4,303	25			
59		42.5	Marginulina	Olig	S	Por	6,590	6,666	24	D	Frio	7,504
60		Gas	Cole	Eoc	S	Por	1,550	1,575	17	MF	Mt. Selman	5,858
		22.5	Govt. Wells	Eoc	S	Por	2,280	2,350	19			
		26	Loma Novia	Eoc	S	Por	2,380	2,450	11			
61		32	Upper Mirando	Eoc	S	Por	2,047	2,055	8	MF	Yegua	3,600
		35.2	Lower Mirando	Eoc	S	Por	2,209	2,232	23			
62		Gas	Frio	Olig	S	Por	1,305	1,318	13	ML	Frio	1,444
63		21	Mirando	Eoc	S	Por	1,944	2,100	16	MF	Yegua	3,546
64		25.5	Upper Hock.	Eoc	S	Por	2,550	2,688	20	ML	Yegua	3,800
		23	Govt. Wells	Eoc	S	Por	2,720	2,760	12			
		26	Loma Novia	Eoc	S	Por	2,820	2,895	30			
65		32.3	Loma Novia	Eoc	S	Por	3,217	3,223	6	ML	Loma Novia	3,223
66		Gas	Mirando	Eoc	S	Por	780	790	8	ML	Mt. Selman	3,171
		21.5	Pettus	Eoc	S	Por	920	975	7			
		21	Cockfield	Eoc	S	Por	1,050	1,070	8			
67		21	McElroy	Eoc	S	Por	905	1,240	20	A	Reklaw	4,645
		23	Jackson-Cockfield	Eoc	S	Por	1,410	1,953	15			
68		44.7	Frio	Olig	S	Por	4,697	4,754	16	A	Jackson	6,407
		42	Govt. Wells	Eoc	S	Por	6,099	6,107	8			
69		21–22	Mirando	Eoc	S	Por	1,920	2,035	12	ML	Yegua	3,011
		Gas & 45	Cockfield	Eoc	S	Por	2,475	2,500	15			
70		22	Mirando	Eoc	S	Por	2,046	2,096	7	ML	Yegua	3,060
		Gas & 45	Cockfield	Eoc	S	Por	2,492	2,524	23			
71		21.5	Miocene	Mio	S	Por	1,400	2,900	20	D	Frio	6,922
		22	Oligocene	Olig	S	Por	3,217	3,238	20			
72		21.5	Cole	Eoc	S	Por	1,748	1,850	12	ML	Carrizo	7,723
		22.5	Govt. Wells	Eoc	S	Por	2,438	2,500	12			
		21.6	Mirando	Eoc	S	Por	2,613	2,800	29			
73		Gas	Hockleyensis	Eoc	S	Por	2,453	2,460	7	ML	Yegua	4,054
		27	Loma Novia	Eoc	S	Por	2,800	2,900	19			
74	PM	62	Frio	Olig	S	Por	6,650	6,683	20	D	Vicksburg	8,893
		52	Frio	Olig	S	Por	7,450	7,480	25			
		48	Frio	Olig	S	Por	7,840	7,875	20			
		56	Frio	Olig	S	Por	8,035	8,074	25			
75		60	Frio	Olig	S	Por	6,533	6,598	15	A	Vicksburg	7,545
		60	Frio	Olig	S	Por	6,998	7,011	10			
		25	Vicksburg	Olig	S	Por	7,219	7,232	12			
76		51.6	Frio	Olig	S	Por	5,917	5,969	52	AF	Vicksburg	7,010
77		51.5	Frio	Olig	S	Por	5,798	5,832	40	AF	Vicksburg	6,566
78		18,7	Cole	Eoc	S	Por	1,782	1,828	22	A	Yegua	3,808
79		48	Frio	Olig	S	Por	7,630	7,646	16	D	Frio *y*	10,286
80		Gas	Frio	Olig	S	Por	360	366	6	MF	Mt. Selman	3,165
		Gas	Mirando	Eoc	S	Por	1,770	1,777	6			
		49	Cockfield	Eoc	S	Por	2,244	2,275	7			
81		22	McElroy	Eoc	S	Por	1,049	1,055	6	ML	Cook Mt.	3,034
82		21	Chernosky	Eoc	S	Por	2,195	2,232	12	MF	Cockfield	2,766

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
83	Loma Novia, *Duval*	1934	7,410	270	20,159,100	3,437,934
84	Loma Valdez, *Webb*	1938	0	10	Gas	0
85	Loma Vista, *Duval*	1936	10	10	17,610	2,995
86	London, *Nueces*	1937	80	40	57,994	11,197
87	Longhorn, *Duval*	1938	820	0	435,284	435,284
88	Lopena, *Zapata*	1934	0	1,040	Gas	Gas
89	Lopez, *Webb, Duval*	1935	3,450	240	8,414,831	1,716,395
90	Los Olmos, *Starr*	1925	240	310	589,497	29,009
91	Los Picachos, *Duval*	1938	20	0	576	0
92	Luby, *Nueces*	1937	2,800	40	4,009,931	2,389,663
93	North Luby, *Nueces*	1939	40	0	9,879	9,879
94	Lundell, *Duval*	1937	580	120	385,061	216,523
95	Magnolia City, *Jim Wells*	1939	40	0	17,022	17,022
96	Martinez, *Zapata*	1929	0	850	Gas	Gas
97	Mathis, *San Patricio*	1924	0	100	Gas	0
98	East Mathis, *San Patricio*	1939	40	40[3]	750	750
99	McAllen, *Hidalgo*	1938	0	240[3]	5,738	4,846
100	Mercedes, *Hidalgo*	1935	0	560[3]	157,454	23,102
101	Mestinas, *Hidalgo*	1935	0	40[3]	See San Salvador	1,598
102	Midway, *San Patricio*	1937	300	0	533,984	240,951
103	Minnie Bock, *Nueces*	1939	475	0	103,410	103,410
104	Mirando City, *Webb*	1921	1,430	500	8,996,689	107,344
105	Mirando Valley,[17] *Zapata*	1921	720	280	936,754	272,825
106	Moca, *Webb*	1932	80	20	976,100	107,292
107	Munson, *McMullen*	1938	150	20	81,825	71,999
108	Muralla (Blanchard), *Duval*	1939	40	0	8,288	8,288
109	Odem, *San Patricio*	1939	0	40[3]	600	600
110	Oilton, *Webb*	1937	700	150	1,224,601	417,121
111	Palangana, *Duval*	1928	50	0	9,846	0
112	Pena, *Duval*	1933	0	40	Gas	0
113	Peters, *Duval*	1933	140	1,400	155,114	22,161
114	Peyote, *Jim Hogg*	1932	0	20	Gas	0
115	Piedre Lumbre, *Duval*	1935	1,000	200	1,307,387	446,126
116	Pietras Pintas, *Duval*	1905	150	0	154,152	3,225
117	Plymouth, *San Patricio*	1935	3,320	120	17,775,635	4,194,376
118	East Plymouth, *San Patricio*	1938	0	120	Gas	Gas

[17] Includes South Mirando Valley.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.
			During 1939		End of 1939			Number of Wells[5]		
	During 1939[4]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing Crude	Artificial Lift	Initial
83	9.9	758	0	5	36	683	1	2	681	200
84	0	1	0	0	1	0	0			450
85	0	2	0	0	0	1	0	0	1	
86	0	4	0	0	1	2	0	1	1	750 1,625
87	0	41	40	0	2	39	0	34	5	575 780
88	2,747.3	13	0	0	0	0	13			925
89	10.2	369	0	3	9	340	1	93	247	760
90	0	107	0	0	3	71	0	0	71	120
91	0	1	0	0	1	0	0	0	0	Pump
92	0	148	45	0	1	147	0	147	0	1,710
93	0	2	2	0	0	2	0	2	0	1,275 450
94	101.5	64	23	0	0	61	3	30	31	640
95	0	2	2	0	0	2	0	2	0	1,450 750
96	66.1	27	0	1	20	0	6			620
97	0	6	0	0	0	0	0			935
98	10.0	2	2	0	1	1	0	1	0	1,450 325
99	45.8	2	1	0	1	0	1[3]			2,025 1,750 2,200
100	1,012.7	7	0	0	5	0	2[3]			2,500 2,750
101	86.1	1	0	0	0	0	1[3]			1,840
102	0	13	0	0	3	10	0	5	5	1,985
103	0	23	23	0	0	23	0	23	0	1,240
104	3.1	295	0	1	9	78	1	0	78	
105	2.1	118	58	2	5	75	1	15	60	35
106	0	12	0	0	0	11	0	0	11	
107	0	14	8	0	1	13	0	0	13	Pump
108	0	2	2	0	0	2	0	2	0	1,050
109	5.9	1	1	0	0	0	1[3]			2,650
110	0	140	0	3	25	110	0	3	107	300 850
111	0	5	0	0	0	0	0	0	0	200
112	0	1	0	0	0	0	0			700
113	1,030.0	20	1	0	3	4	3	4	0	750
114	0	1	0	0	0	0	0			
115	323.3	133	52	3	4	122	2	50	72	500 400
116	0	29	4	0	3	2	0	0	2	500
117	95.5	181	15	0	2	178	1	178	0	2,200 1,100 650
118	54.7	2	1	0	1	0	1			1,950 1,800

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
		Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
83		26	Loma Novia	Eoc	S	Por	2,550	2,705	25	ML	Cook Mt.	4,200
		22.5	Mirando	Eoc	S	Por	2,846	2,900	15			
84		Gas	Cole	Eoc	S	Por	1,790	1,812	19		Yegua	3,528
85		26	Loma Novia	Eoc	S	Por	2,914	2,922	7½	ML	Cook Mt.	4,732
86		25.3	Catahoula	Olig	S	Por	4,698	4,730	8	Nf	Frio	7,424
		Gas & 51	Catahoula	Olig	S	Por	4,752	4,906	10			
87		44	Cole	Eoc	S	Por	4,033	4,064	10	AF	Yegua	6,011
		43.6	Govt. Wells	Eoc	S	Por	4,885	4,900	6			
88		Gas	Queen City	Eoc	S	Por	2,147	2,170	23	A	Carrizo	3,502
89		22	Mirando	Eoc	S	Por	2,126	2,144	18	ML	Yegua	3,437
90		18.5	Frio	Olig	S	Por	250	700	17	MF	McElroy	2,612
91		24	Govt. Wells	Eoc	S	22–26	2,166	2,196	15	MF	Govt. Wells	2,196
92		51.6	Catahoula	Olig	S	Por	4,306	4,354	15	NF	Frio	7,595
		49	Heterostegina	Olig	S	Por	5,009	5,087	20			
		50	Heterostegina	Olig	S	Por	5,155	5,175	10			
93		51	Catahoula	Olig	S	Por	4,347	4,361	10	NF	Frio	7,440
		48	Heterostegina	Olig	S	Por	5,073	5,085	12			
94		21	Cole	Eoc	S	Por	1,513	1,530	10	MF	Jackson	2,698
95		43.8	Frio	Olig	S	Por	5,436	5,446	10	A	Vicksburg	6,592
		45	Frio	Olig	S	Por	5,704	5,714	10			
96		Gas	Hockleyensis	Eoc	S	Por	1,921	1,927	6	ML	Yegua	3,514
97		Gas	Miocene	Mio	S	Por	2,375	2,414	10	MF	McElroy	5,526
98		54	Frio	Olig	S	Por	4,417	4,422	5	Nf	Jackson	6,348
		35.5	Frio	Olig	S	Por	5,258	5,270	12			
99		61.5	Frio	Olig	S	Por	5,970	5,994	24	D	Vicksburg	7,507
		58–60	Frio	Olig	S	Por	6,500	6,955	20			
		55	Vicksburg	Olig	S	Por	7,415	7,498	25			
100		49.2–61	Frio	Olig	S	Por	7,430	7,524	16	DF	Vicksburg	9,618
		50–60	Frio Vicksburg	Olig	S	Por	7,920	9,000[16]	15			
101		52–60	Frio	Olig	S	Por	6,658	6,748	90	D	Frio	8,123
102		29	Frio	Olig	S	Por	5,323	5,370	15	D	Frio	7,003
103		23.6	Catahoula	Olig	S	Por	3,794	3,835	15	D	Frio	6,011
104		21.4	Hockleyensis	Eoc	S	Por	1,530	1,540	10	ML	Reklaw	5,000
		45	Cockfield	Eoc	S	Por	1,925	1,935	10			
105		21	Upper-Hock.	Eoc	S	Por	1,415	1,425	7	ML	Cook Mt.	3,660
		20.5	Mirando	Eoc	S	Por	1,790	2,000	8			
106		21	Mirando	Eoc	S	Por	900	950	10	MF	Yegua	2,178
107		22.5	Mirando	Eoc	S	Por	1,201	1,213	12	ML	Pettus	1,501
108		42.6	Pettus	Eoc	S	Por	4,710	4,715	5	ML	Pettus	4,822
109		57	Frio	Olig	S	Por	6,995	7,000	5	y	Frio	7,295
110		22	Mirando	Eoc	S	Por	1,880	2,025	12	ML	Yegua	3,151
		Gas	Cockfield	Eoc	S	Por	2,407	2,473	15			
111		16	Catahoula	Olig	L	Cav	450	455	5	DS	Mt. Selman	5,454
		45	Jackson	Eoc	S	Por	2,730	2,744	14			
112		Gas	Frio	Olig	S	Por	1,915	1,932	17	MF	Caddell	3,620
113		Gas	Cole	Eoc	S	Por	1,750	1,760	5	ML	Yegua	3,309
		Gas	Govt. Wells	Eoc	S	Por	2,410	2,451	20			
		23	Mirando	Eoc	S	Por	2,610	2,635	15			
114		Gas	Govt. Wells	Eoc	S	Por	2,246	2,262	16	ML	Yegua	3,210
115		Gas	Cole	Eoc	S	Por	1,324	1,350	7	ML	Yegua	3,250
		20.5	Govt. Wells	Eoc	S	Por	1,950	2,080	12			
		22.5	Loma Novia	Eoc	S	Por	2,100	2,174	10			
116		13	Catahoula	Olig	S	Por	180	580	20	DS	Mt. Selman	5,902
		47	Hockleyensis	Eoc	S	Por	3,462	3,623	26			
117		32	Frio	Olig	S	Por	5,500	5,525	10	AF	Frio	7,253
		34.2	Frio	Olig	S	Por	5,650	5,675	12			
		38	Frio	Olig	S	Por	5,900	5,920	10			
		40	Frio	Olig	S	Por	6,156	6,159[18]	3			
118		Gas	Heterostegina	Olig	S	Por	4,808	4,836	20	AF	Frio	6,750
		Gas	Frio	Olig	S	28–34	5,110	5,136	15			

[16] Found productive on tests. Not producing

[18] Perforations.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
119	Premont, *Jim Wells*	1933	600	280	591,652	116,245
120	East Premont, *Jim Wells*	1937	240	120[3]	113,064	53,286
121	Rancho Solo,[19] *Duval*	1935	350	160	178,024	136,818
122	Randado, *Jim Hogg*	1926	765	435	4,646,150	88,132
123	Reiser, *Webb*	1909	20	1,270	4,000	0
124	Reynolds, *Jim Wells*	1939	580	0	117,513	117,513
125	Rhode, *McMullen*	1936	0	650	Gas	Gas
126	Ricaby,[20] *Starr*	1937	100	0	25,454	17,600
127	Richard King, *Nueces*	1937	520	100	397,843	263,720
128	Rincon,[21] *Starr*	1938	80	240[3]	24,530	12,906
129	Rio Grande City, *Starr*	1932	150	60	378,380	30,440
130	Riverside, *Nueces*	1938	80	80[3]	29,929	29,929
131	Robston, *Nueces*	1939	40	0	6,915	6,915
132	Roma, *Starr*	1927	20	280	19,165	1,021
133	Sacatosa, *Starr*	1938	0	10	Gas	0
134	Sam Fordyce,[22] *Starr, Hidalgo*	1934	1,600	900	7,369,991	819,868
135	Sandia, *Jim Wells*	1929	50	120	21,504	767
136	San Diego, *Jim Wells*	1934	0	120	Gas	0
137	San Jose, *McMullen*	1938	10	10	450	0
138	San Salvador, *Hidalgo*	1938	0	40[3]	43,521[24]	26,672
139	Santo Domingo, *Starr*	1936	0	50	Gas	0
140	Sarnosa, *Duval*	1932	690	180	2,238,846	178,223
	Saxet, *Nueces*					
141	Shallow	1923	3,850	3,800	40,424,232	8,559,514
142	Deep	1935	2,450	3,400[2]		
143	Seabury, *Starr*	1939	10	0	250	250
144	Sejita, *Duval*	1939	0	40[3]	Distillate	Distillate
145	Seven Sisters, *Duval*	1934	4,420	240	10,601,387	2,134,297

[19] Includes Rancho Solo Extension.
[20] Includes North Ricaby.
[21] Includes North Rincon.
[22] Includes North Sam Fordyce.
[24] This total includes production for Mestenas field.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.
			During 1939		End of 1939			Number of Wells[5]		
	During 1939[4]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing Crude	Artificial Lift	Initial
119	235.9	42	1	0	10	29	2	2	27	800 900
120	22.6	8	3	0	2	5	1[3]	5	0	2,000 1,600 1,975 2,200 2,000
121	19.1	37	17	0	4	29	1	4	25	800
122	0	191	0	1	6	89	0	0	89	
123	0	18	0	0	0	0	0			
124	0	29	29	0	1	28	0	28	0	2,750 1,475 1,850
125	470.9	10	0	0	2	0	8			650
126	0	10	6	2	3	3	0	0	3	175 Pump 235
127	174.0	31	19	0	2	28	1	28	0	650 1,250 550
128	40.8	5	4	0	1	2	2[3]	2	0	1,700
129	7.4	30	0	0	4	15	1	0	15	
130	124.3	5	3	0	1	2	1[3]	2	0	1,450
131	0	1	1	0	0	1	0	1	0	950
132	0	5	0	0	0	1	0	0	1	
133	0	1	0	0	1	0	0			400
134	93.6	256	17	5	35	131	1	39	92	400 1,050 1,250 1,150 2,800
135	0	6	0	0	3	2	0	1	1	1,050 1,227 1,750
136	0	2	0	0	2	0	0			1,200
137	0	2	0	1	1	0	0			245
138	1,436.2	1	0	0	0	0	1[3]			3,200
139	0	2	0	0	2	0	0			1,050
140	0	57	0	5	5	41	0	0	41	
141	38,092.0	756	34	11	59	350	28	176	174	1,325
142						162	42[2]	115	47	2,000 2,300 3,400
143	0	1	1	0	0	1	0	1	0	
144	Gas	1	1	0	0	0	1[3]			2,150
145	199.1	450	6	2	17	401	4	63	338	225 625 200 460

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
		Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
119		22.8	Catahoula	Olig	S	Por	2,250	2,350	10	D	McElroy	7,135
		24	Frio	Olig	S	Por	3,165	3,265	11			
120		60	Frio	Olig	S	Por	5,365	5,370[18]	5y	D	Jackson	8,162
		54	Frio	Olig	S	Por	5,465	5,480	15			
		36–60	Frio	Olig	S	Por	5,626	5,632[18]	6y			
		Distillate	Frio	Olig	S	Por	5,807	6,138[23]	10y			
		36.5	Vicksburg	Olig	S	Por	6,582	6,694	10y			
121		19.4–21.5	Cole	Eoc	S	Por	1,826	1,869	12	ML	Yegua	3,777
		Gas	Govt. Wells	Eoc	S	Por	2,555	2,569	14			
122		20.5	Cole	Eoc	S	Por	1,225	1,275	9	MF	Mt. Selman	5,222
123		16	Jackson-Cockfield	Eoc	S	Por	390	1,010	15	ML	Mt. Selman	3,247
124		31	Frio	Olig	S	Por	4,817	4,928	10	A	Jackson	6,025
		41	Frio	Olig	S	Por	5,110	5,119	9			
		35.5	Frio	Olig	S	Por	5,130	5,254	15			
125		Gas	Cole	Eoc	S	Por	1,800	1,822	12	MF	Yegua	3,534
126		21–23	Frio	Olig	S	Por	1,294	1,317	8	ML	Jackson	2,844
		21.5	Frio	Olig	S	Por	1,432	1,437	5			
		30	Frio	Olig	S	Por	1,604	1,611	7			
127		22	Frio	Olig	S	Por	4,000	4,026	15	AF	Hockleyensis	7,567
		37	Frio	Olig	S	Por	5,251	5,258	7			
		39	Frio	Olig	S	Por	5,380	5,440	15			
		38	Vicksburg	Olig	S	Por	6,133	6,143	10			
128		41.4–59	Vicksburg	Olig	S	26–39	4,154	4,294	20	A	Yegua	6,862
129		27.3	Frio	Olig	S	Por	1,350	1,450	8	MF	Jackson	3,258
130		33.5–51	Frio	Olig	S	Por	4,888	5,000	25	A	Vicksburg	7,510
131		42.5	Frio	Olig	S	Por	5,548	5,582	20	A	Frio	7,089
132		Gas	Frio-Jackson	Olig, Eoc	S	Por	192	200	8	A	Reklaw	4,827
		35	Queen City	Eoc	S	Por	3,560	3,590	6			
133		Gas	Govt. Wells	Eoc	S	Por	1,650	1,661	11	ML	McElroy	1,794
134		21.4	Frio	Olig	S	Por	2,737	2,753	16	AF	Mt. Selman	9,708
		23.5	Frio	Olig	S	Por	2,831	2,853	22			
		23.2	Frio	Olig	S	Por	2,925	3,125	20			
		Gas	Frio	Olig	S	Por	3,183	3,196	13			
		Gas	Jackson	Eoc	S	Por	5,840	5,900	20			
135		Gas	Catahoula	Olig	S	Por	2,910	2,917	7	AF	Hockleyensis	5,701
		41.5	Frio	Olig	S	Por	4,002	4,023	13			
		52	Cole	Eoc	S	Por	5,151	5,163	9			
136		Gas	Frio	Olig	S	Por	2,952	2,976	10	A	Yegua	6,480
137		23	Cole	Eoc	S	Por	1,147	1,163	16	ML	Yegua	2,370
138		Gas	Frio	Olig	S	Por	7,630	7,645	15	A	Frio	8,002
139		Gas	Frio	Olig	S	Por	2,461	2,616	25	A	Yegua	6,005
140		22	Govt. Wells	Eoc	S	Por	2,300	2,500	40	MF	Yegua	4,073
141		24	Lagarto-Oakville	Mio	S	Por	1,000	3,150	15	DF	Frio-Vicksburg	10,042
		24	Cataboula	Olig	S	Por	3,900	4,500	18			
		24	Discorbis-Het.	Olig	S	Por	4,700	4,880	18			
142		38.2–58.5	Frio	Olig	S	Por	5,500	6,900	18			
		56	Frio	Olig	S	Por	7,250	7,390	140			
		58	Frio-Vicksburg	Olig	S	Por	9,900	9,927	20			
143		22.6	Frio	Olig	S	Por	1,328	1,333	5	ML	Jackson	2,757
144		51.7	Govt. Wells	Eoc	S	Por	5,334	5,345	11		Yegua	6,747
145		21	Cole	Eoc	S	Por	1,710	1,720	10	MF	Cook Mt.	4,404
		20.5	Chernosky	Eoc	S	Por	2,112	2,225	20			
		23	Govt. Wells	Eoc	S	Por	2,470	2,485	15			
		27	Loma Novia	Eoc	S	Por	2,660	2,690	15			
		23	Mirando	Eoc	S	Por	2,540	2,565	10			
		Gas	Yegua	Eoc	S	Por	3,037	3,071	15			

[23] Found productive on tests—not producing.

ft. of gas per day and with the assumed average rate of 25 bbl. of condensate per 1,000,000 cu. ft. of gas per day, these three plants will probably supply an additional 10,000 bbl. of distillate per day from the same district. These three plants, together with the present operating Agua Dulce plant, would probably yield 16,500 bbl. of distillate per day by the end of 1940. There is no question that recycling plants in the South Texas area will be very important economically.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
146	South Seven Sisters, *Duval*	1937	330	0	459,801	239,923
147	Sinton, *San Patricio*	1934	225	100	82,268	4,770
148	Southland, *Duval*	1939	80	0	16,622	16,622
149	Stratton, *Nueces*	1931	0	1,000[g]	388,074	236,099
150	Sullivan (South Agua Dulce), *Nueces*	1936	120	680[g]	92,133	14,755
151	Sullivan City, *Hidalgo*	1939	100	160	24,665	24,665
152	Sun, *Starr*	1938	680	80	151,477	139,782
153	Sweden, *Duval*	1937	150	160	242,606	96,578
154	Taft, *San Patricio*	1935	720	80	3,366,222	998,604
155	Tarancahuas, *Duval*	1939	20	0	1,000	1,000
156	Tesoro, *Duval*	1938	140	80	125,191	97,885
157	Thomas Lockhart, *Duval*	1937	100	0	17,146	155
158	Turkey Creek (West Saxet), *Nueces*	1938	890	40	2,062,593	1,216,736
159	Villa, *Zapata*	1932	0	120	Gas	0
160	Volpe, *Webb*	1939	150	0	21,317	21,317
161	Wade City, *Jim Wells*	1939	0	80[g]	3,128	3,128
162	Wentz, *McMullen*	1932	0	80	Gas	0
163	Weslaco, *Hidalgo*	1938	0	40[g]	2,125	137
164	White Point, *San Patricio*	1930	100	3,900	135,415	18,961
165	East White Point, *San Patricio*	1938	2,950	120	2,315,588	1,947,125
166	Woods, *Starr*	1936	0	120	Gas	0
167	Wray, *Zapata*	1933	0	80	Gas	0
168	Young (Charco Blanco), *Starr*	1938	0	20	Gas	0
	Total		97,790	70,910[g]	273,187,554	55,105,506

The octane value of straight-run distillate from the present plants varies from 52 to 70; however, at the present time, in two of the abovementioned fields, small reforming plants are being planned, which are capable of handling 2000 bbl. of distillate per day and which will raise the octane values to 80 plus. A product with this high octane value would probably command a price in the neighborhood of $2.50 per barrel.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.
			During 1939		End of 1939			Number of Wells[5]		
	During 1939[4]	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[6]	Producing Gas[6]	Flowing Crude	Artificial Lift	Initial
146	0	33	0	0	2	31	0	0	31	
147	177.9	7	0	0	1	1	1	1	0	2,200 1,160
148	0	4	4	0	2	2	0	2	0	600 865
149	16,836.3	12	2	0	6	0	6[3]			1,850 2,110 1,900
150	306.1	7	0	0	5	1	1[3]	1	0	2,000 2,200 2,300
151	447.2	9	9	0	5	3	1	3	0	1,100 1,375
152	151.5	19	15	0	3	15	1	15	0	1,800 750 730 800 2,000
153	641.0	12	0	0	2	8	2	4	4	120 300 710
154	46.8	73	0	0	2	70	1	59	11	600 650 375
155	0	1	1	0	0	1	0	1	0	
156	39.5	8	4	0	2	5	1	5	0	670
157	0	4	0	0	4	0	0	0	0	1,450
158	0	60	7	0	0	60	0	47	13	550 375 875 1,400 780
159	0	3	0	0	0	0	0			375
160	0	12	12	0	0	12	0	4	8	Pump
161	58.4	2	2	0	1	0	1[3]			1,850
162	0	3	0	0	0	0	0			200
163	13.4	1	0	0	1	0	0			2,950
164	2,134.1	48	2	2	8	2	7	1	1	765 2,000 500
165	172.9	161	131	0	2	157	2	157	0	500 500 950
166	0	4	0	0	2	0	0			460
167	0	3	0	0	0	0	0			150
168	0	1	0	0	0	0	0			960
		11,029	1,320	113	862	7,421	408[3]	2,486	4,935	

The possibilities for additional recycling plants in the South Texas area are very encouraging and tests have shown that the recovery factors in some of the fields certainly warrant such construction. Each field, of course, has its own peculiarities, which necessitate accurate tests and data before final conclusions are drawn. From an economical standpoint and by employing a more or less "rule of thumb" method, installation of recycling plants erected on a pressure capacity of 1250

TABLE 1.—(*Continued*)

		Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
Line Number	Repressuring Operation[d]	Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
146		22	Frio	Olig	S	Por	1,559	1,566	7	MF	Yegua	3,100
		27	Loma Novia	Eoc	S	Por	2,646	2,656	10			
147		44	Frio	Olig	S	Por	5,415	5,437	15	A	Frio	7,438
		33	Frio	Olig	S	Por	5,880	5,905	10			
148		44.8	Pettus	Eoc	S	Por	5,286	5,298	10	MF	Yegua	5,923
		46	Cockfield	Eoc	S	Por	5,355	5,365	10			
149	PM	58	Frio	Olig	S	Por	4,788	4,801	13	D	Frio	6,904
		49.3	Frio	Olig	S	Por	5,992	6,002	10			
		56	Frio	Olig	S	Por	6,273	6,300	27			
		54	Frio	Olig	S	Por	6,481	6,485	4			
150		43	Frio	Olig	S	Por	5,756	5,780	15	DF	Frio	6,912
		Distillate	Frio	Olig	S	Por	6,400	6,410	10			
		Distillate	Frio	Olig	S	Por	6,788	6,800	12			
151		24.8	Frio	Olig	S	Por	3,414	3,463	15	AF	Mt. Selman	9,708
		Gas	Frio	Olig	S	Por	3,936	3,983	25			
152		52	Frio	Olig	S	Por	4,111	4,142	15	A	Vicksburg	5,926
		46	Frio	Olig	S	Por	4,610	4,670	15			
		43.7	Frio	Olig	S	Por	4,842	4,858	16			
		45.1	Frio	Olig	S	Por	4,900	4,972	10			
		47.9	Vicksburg	Olig	S	Por	5,115	5,135	20			
153		43	Chernosky	Eoc	S	Por	4,895	4,915	20	AF	Yegua	6,531
		46	Upper Govt. Wells	Eoc	S	Por	5,072	5,091	19			
		Gas	Lower Govt. Wells	Eoc	S	Por	5,100	5,116	16			
		58	Cockfield	Eoc	S	Por	5,845	5,869	24			
154		24	Catahoula	Olig	S	Por	3,975	4,010	20	DF	Frio	6,926
		25.6	Catahoula	Olig	S	Por	4,300	4,375	20			
		24.5	Heterostegina	Olig	S	Por	4,900	4,934	20			
155		21.3	Frio	Olig	S	Por	2,014	2,035	15	ML	Caddell	3,309
156		Gas	Pettus	Eoc	S	Por	4,828	4,848	15	NF	Yegua	5,541
		45	Pettus	Eoc	S	Por	5,080	5,136	20			
157		56.8	Pettus	Eoc	S	Por	4,659	4,672	13	MF	Yegua	5,502
158		22.6	Catahoula	Olig	S	Por	3,846	3,860	14	DF	Frio	7,511
		25	Catahoula	Olig	S	Por	4,025	4,080	10			
		43	Frio	Olig	S	Por	5,641	5,664	19			
		35.2	Frio	Olig	S	28	5,794	5,872	19			
		28	Frio	Olig	S	Por	6,430	6,456	26			
159		Gas	McElroy	Eoc	S	Por	1,657	1,664	7	ML	Cook Mt.	3,000
160		22.5	Mirando	Eoc	S	Por	2,458	2,488	8	ML	Yegua	3,717
161		47.7	Frio	Olig	S	Por	4,788	4,813	10	ML	Jackson	5,411
162		Gas	Cole	Eoc	S	Por	370	382	12	N	Yegua	1,654
163		51	Frio	Olig	S	23–27	8,634	9,005	15	A	Vicksburg	9,182
164		Gas	Lagarto-Oakville	Mio	S	Por	1,900	2,800	10	AF	Frio	7,211
		31	Heterostegina	Olig	S	Por	4,880	4,961	10			
		29.8	Frio	Olig	S	Por	5,672	5,676	4			
165		Gas	Oakville	Mio	S	Por	2,495	2,505	10	AF	Vicksburg	8,383
		Gas	Catahoula	Olig	S	Por	4,010	4,015	5			
		39.6	Frio	Olig	S	24–33	5,630	5,680	30			
166		Gas	Frio	Olig	S	Por	963	975	12	A	Jackson	3,360
167		Gas	Jackson	Eoc	S	Por	348	370	22	ML	Mt. Selman	2,000
168		Gas	Jackson	Eoc	S	Por	2,708	2,730	15	MF	Jackson	3,008

to 3000 lb. cost to install from approximately $3500 to $7000 per million cubic feet of gas per day recycled. The cost depends on the recycling pressure and the temperature control of the plant.* Because of the peculiarities of each field and the high cost of building recycling plants, and the question as to whether or not these plants will become profitable in the future, it is extremely important that tests be made on the wells before any recycling plant is built. Recent methods have been devised for testing the economical and engineering phases of the value of building these plants in various fields. These tests and reports give information on plant designing, plant operations and economics of their operations.

It is predicted that the South Texas area in the future will not only be a testing ground for recycling plants but also one of the most profitable areas where these plants will operate.

Duval County, Laredo District

Southland Field.—On April 13, Henderson, Coquat Amselma Oil Co. completed Southland Insurance Company's No. 1, Flores Grant, several miles south of the town of Sweden, from Pettus sand at 5286 to 5298 ft. to discover the Southland field; flow of 170 bbl. of 44.8 gravity oil was through $\frac{5}{32}$-in. choke under 600 lb. tubing pressure and 1240 lb. casing pressure. In October, Hiawatha Oil Company's Southland No. 3*A* flowed 198 bbl. of 46° gravity oil per day from perforations at 5355 to 5365 ft. in Cockfield sand. Flow was through $\frac{5}{32}$-in. choke under 865 lb. tubing pressure and 1175 lb. casing pressure.

Muralla Field.—Atlee Parr No. 1, J. B. Blanchard et al., sec. 298, was completed on May 22 in Pettus sand at 4710 to 4715 ft. for a flow of 45 bbl. of 42.6° gravity oil with much gas to discover the Muralla field. Production was through $\frac{3}{32}$-in. choke under 1050 lb. tubing pressure and 1550 lb. casing pressure.

North Casa Blanca Field.—Transwestern Oil Company's Duval County Ranch Co. No. 21, sec. 297, was completed on May 28 in Cole sand found at 1045 to 1054 ft. It produced 65 bbl. of 20° gravity oil daily on pump.

Chiltipin Field.—On June 30, Wm. M. Nicholls J. T. Graham No. 1, sec. 572, produced 46° gravity oil with gas from perforations from 4784 to 4790 ft., in Pettus sand at 4760 to 4795 ft.; production was through $\frac{1}{8}$-in. choke under 1440 lb. tubing pressure and 1660 lb. casing pressure.

Sejita Field.—Standard of Texas completed Jack Casey No. 1, sec. 4, on Oct. 25, for a flow of 10 bbl. of 50° gravity distillate and 2,500,000 cu. ft. of gas per day through $\frac{5}{32}$-in. choke under 2150 lb. tubing pressure, casing sealed. This discovery of the Sejita field drilled to 6747 ft., and found a Yegua sand from 6588 to 6611 ft.; the well was then plugged back for completion in Government Wells sand from 5334 to 5345 feet.

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* Private communication: E. O. Buck, Gas Laboratories, Inc., Houston, Texas.

TABLE 2.—*Summary of Drilling Operations in South Texas*

Important Wildcats Drilled in 1939

	County	Well Name and Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
	LAREDO DISTRICT				
1	Duval	Graham No. 1, survey 572	4,838	Goliad	Pettus
2	Duval	Parr No. 1, Rogers survey	4,822	Goliad	Pettus
3	Duval	Southland No. 1*A*, Flores grant	5,298	Goliad	Pettus
4	Duval	Casey No. 1, Copita Farms, blk. 26, sec. 4	6,747	Goliad	Yegua
5	Duval	Gorman-Hoffman No. 1, sec. 119	3,309	Goliad	Pettus
6	Duval	Miller No. 2*A*, Longhorn field	4,038	Goliad	Jackson
7	Duval	D.C.R.C. No. 21, survey 297	1,059	Catahoula	Cole
8	Duval	Welder No. 2*G*, Seven Sisters	3,115	Goliad	Yegua
9	Duval	Southland No. 3*A*, Southland	5,365	Goliad	Pettus
10	Duval	J. Mew No. 1, Fitzsimmons	4,285	Goliad	Pettus
11	Duval	A. Weil No. 1, sec. 113	2,806	Goliad	Loma Novia
12	Duval	A. Weil No. 2, sec. 113	2,836	Goliad	Loma Novia
13	Duval	Spence No. 2, Tesoro	4,848	Goliad	Pettus
14	Duval	Peter No. 1*A*, Rancho-Solo	1,839	Goliad	Cole
15	Jim Hogg	I. Gutierrez No. 1, blk. 4, Mayfair subd.	3,223	Goliad	Loma Novia
16	Jim Hogg	King Ranch-Colorado No. 1, Colorado	3,041	Catahoula	Cockfield
17	McMullen	Ezzell No. 96, So. Calliham area, sec. 42	1,537	Catahoula	Jackson
18	Starr	Seabury No. 1, Porcion 80	2,757	Goliad	Jackson
19	Starr	Ricaby No. 1, Porcion 83	1,305	Goliad	Frio
20	Starr	Cameron No. 1, survey 228	4,178	Goliad	Vicksburg
21	Starr	Guerra Fee No. 2, Farrias grant	6,566	Goliad	Vicksburg
22	Starr	Lester No. 1, No. Ricaby field	1,437	Goliad	Frio
23	Starr	McKinney No. 3, Sun field	5,068	Goliad	Vicksburg
24	Starr	McKinney No. 4, Sun field	5,382	Goliad	Vicksburg
25	Starr	Olivarez No. 2, Sun field	5,650	Goliad	Vicksburg
26	Starr	Speer No. 1, Sun field	5,188	Goliad	Vicksburg
27	Starr	Montalvo No. 1, Sun area	5,134	Goliad	Vicksburg
28	Starr	T. B. Slick No. 1*C*, sec. 528	4,320	Goliad	Vicksburg
29	Starr	Lopez No. 1, Sun area, sec. 237	4,965	Goliad	Frio
30	Starr	Dallas J. T. L. Bank No. 1, Rincon area, sec. 226	5,025	Goliad	Jackson
31	Starr	Garcia No. 1, Barbacoas area, sec. 90	6,567	Goliad	Yegua
32	Webb	Adami No. 1, A. B. & M. survey, sec. 345	999	Frio	Mirando
33	Webb	Benavides No. 5*B*, B. S. & F. survey, sec. 695	2,466	Goliad	Mirando
34	Webb	Benavides No. 1, West Cole area, sec. 693	2,350	Goliad	Mirando
35	Webb	A. M. Bruni No. 7, Cole-Bruni	8,959	Goliad	Wilcox
36	Zapata	R. Lopez No. 1, blk. 5, survey 113	1,798	Frio	Mirando
37	Zapata	R. Lopez No. 4, So. Mirando Valley	1,810	Frio	Mirando
38	Zapata	Vela No. 1, Porcion 20, Lopena area	2,508	Jackson?	Mt. Selman
	SOUTH CORPUS CHRISTI DISTRICT				
39	Brooks	McGill No. 5, Kelsey field	6,407	Sand dunes	Jackson
40	Hidalgo	Ed. Sullivan No. 1, Sam Fordyce area, Porcion 39	3,465	Goliad	Frio
41	Hidalgo	V. G. Chapa No. 1, Sullivan City Field, Porcion 40	3,986	Goliad	Frio
42	Hidalgo	R. E. Harding No. 1, La Blanca	8,074	Beaumont	Frio
43	Hidalgo	McDougall No. 1, La Blanca	Plug-back	Beaumont	Frio
44	Hidalgo	E. M. Card No. 1, McAllen	7,507	Beaumont	Vicksburg
45	Hidalgo	Annie Sheldon No. 1, Porcion 40	4,170	Goliad	Frio
46	Jim Wells	Von Blucher No. 1, Best survey	7,565	Lissie	Vicksburg
47	Jim Wells	Clark No. 1, Lopez grant	5,330	Lissie	Vicksburg
48	Jim Wells	Sam Maun No. 1, La Gloria subd.	7,545	Lissie	Vicksburg
49	Jim Wells	Adams No. 1, Adams survey	4,689	Lissie	Vicksburg
50	Jim Wells	Shear No. 1, A. B. & M. survey	6,592	Lissie	Vicksburg
51	Jim Wells	Smith No. 1, La Trinidad grant	5,251	Lissie	Frio
52	Jim Wells	Hoffman No. 1, sec. 8	5,826	Lissie	Hockleyensis
53	Jim Wells	Miller No. 1, Agua Dulce grant	5,617	Lissie	Vicksburg
54	Jim Wells	Pundt No. 1, Poitevent survey	5,411	Lissie	Vicksburg
55	Jim Wells	Perales No. 1, Ben Bolt	5,467	Lissie	Vicksburg
56	Jim Wells	Muil No. 1, Clark-Muil field	5,330	Lissie	Frio

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Nicholls Oil Co.	Spray	10	1/8	1,660	1,440	Discovery Chiltipin field
2	Blanchard Oil Co.	45		3/32	1,550	1,050	Discovery Muralla field
3	Henderson & Coquat	170		5/32	1,240	600	Discovery Southland field
4	Standard of Texas	10	2½	3/16	Sealed	2,150	Discovery Sejita field
5	Cox and Hamon	300		3/8	100	0	Discovery Tarancahuas field
6	Longhorn Drilling	105		1/8	740	575	New 4000-ft. Jackson sand, Longhorn
7	Transwestern Oil Co.	65			Pumping		Discovery North Casa-Blanca
8	Wellington Oil Co.		20				New 3000-ft. Yegua sand, Seven Sisters
9	Hiawatha Oil Co.	198		5/32	1,175	865	New 5300-ft. Pettus sand, Southland
10	H. J. Porter	140		9/64	620	400	SW. extension Fitzsimmons
11	Magnolia Petr. Co.		6.9		890 (rock-pressure)		Ext. Govt. Wells sand, 2 miles SW. Hoffman
12	Magnolia Petr. Co.	42 (Jetting)		1/2	200		Ext. Loma-Novia sand, 2 miles SW. Hoffman
13	Magnolia Petr. Co.		Gas				New 4800-ft. sand and Rault, Tesoro
14	Clark & Cowden		5				Ext. Rancho Solo
15	Mayfair Oil Co.	35		Pumping			Discovery Holland-Hebbronville field
16	Humble O. & R. Co.	435		3/8	700	225	Extension Colorado
17	Edwin M. Jones	25		Pumping			Extension South Calliham
18	Clopton & Mitchell	25		Open tubing	325		Discovery Seabury field
19	Bishop, Moss & Owens	120		Pumping			Discovery North Ricaby field
20	Transwestern Oil Co.	145		11/64	610	365	Discovery North Rincon field
21	Magnolia Petr. Co.	80	4.36	9/64	2,260	2,075	Discovery South La Reforma field
22	Howard Bass	100		Pumping			New 1400-ft. Frio sand, North Ricaby
23	Sun Oil Co.	119		1/8	650	750	New 4650-ft. Frio sand, Sun
24	Sun Oil Co.	25	5	1/8			New 4600-ft. Frio sand, Sun
25	Sun Oil Co.	40	Gas	1/8	1,800 (working)		New 4100-ft. Frio sand, Sun
26	Sun Oil Co.	208		3/16	1,475	800	New 4900-ft. Frio sand, Sun
27	Sun Oil Co.	78		3/16	600	175	1½ mile NW. ext., Sun
28	W. R. Davis	140		5/32	1,450	850	SW. extension, Rincon
29	Sun Oil Co.	72		1/8	1,100	460	Extension, Sun
30	Davenport & Hoffer	22	4	1/4		1,350	North ext., Rincon
31	Magnolia Petr. Co.						Dry deep test
32	Gordon Johnson	35		Pumping			Discovery Adami field
33	Magnolia Petr. Co.	90		Pumping			Discovery Volpe field
34	V. G. Schimmel	96		Pumping			Extension West Cole
35	Tide Water Associated		Completing				Deep test Wilcox Zone
36	Interstate Minerals	35	Gas	3/16	450	380	Discovery South Mirando Valley
37	Interstate Minerals	84		5/16	425	330	East ext., South Mirando Valley
38	Harper & Smith						Dry test
39	Humble O. & R. Co.	63		3/16	1,400	1,050	New 6100-ft. Jackson sand, Kelsey
40	Fohs Oil Co.	76	0.15	5/32	1,450	1,100	Discovery Sullivan City field
41	John Messenger	Spray	3	11/64	1,500	1,375	New 3900-ft. Frio sand, Sullivan City
42	Pantano Oil Co.	80	Gas	3/8	3,850 (working)		New 8000-ft. Frio sand, La Blanca
43	Pantano Oil Co.	100	Gas	7/16	2,700 (working)		New 7400-ft. Frio sand, La Blanca
44	R. E. Harding	100	6	3/8	2,800	2,200	Production from 7400-ft. Vicksburg sand, McAllen
45	Fohs Oil Co.	15	Gas	10/64	1,600	1,350	East extension, Sullivan City
46	Shell Petr. Co.	32	1.3	3/64	3,600 (working)		Discovery Blucher field
47	Gravis & Doran	16	3	9/64	1,450	1,400	Discovery Clark Muil field
48	Magnolia Petr. Co.	165	5.6	5/16	2,170	2,000	Discovery La Gloria field
49	Ike-Howeth	272		3/16	1,250	835	Discovery West Alfred field
50	Gillespie & Sons	145	Gas	1/8	2,000	1,450	Discovery Magnolia City field
51	Bridwell Oil Co.	196		1/8	1,000	875	Discovery Ben Bolt field
52	Parr & Delaney	70		3/32	1,300	850	Discovery Camada field
53	Texas Gulf Producing	50	3	5/64	1,950	1,850	Discovery Reynolds field
54	Hunter & Quinn	30	3	7/64	1,900	1,850	Discovery Wade City field
55	Mosser et al.		20	3/32	2,100	2,100	New 5300-ft. Vicksburg sand, Ben Bolt
56	Gravis & Doran	150		1/8	1,325	900	New 5300-ft. Frio sand, Clark-Muil

Tarancahuas Field.—This field was opened on Dec. 19 by Cox and Hamon and Gorman's Hoffman No. 1, sec. 119, two miles east of Hoffman field, when it produced 300 bbl. of 21.3° gravity crude daily through $\frac{3}{8}$-in. choke, under no tubing and 100 lb. casing pressure. Flow was from a Frio sand, unusual for this immediate area, through perforations

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	County	Well Name and Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
57	Jim Wells	Mosser 4*A*, Reynolds	5,220	Lissie	Vicksburg
58	Jim Wells	Fee 2*F*, Reynolds	5,172	Lissie	Vicksburg
59	Jim Wells	Dunlap No. 1, East Premont	6,766	Lissie	Vicksburg
60	Jim Wells	D. O. Maun No. 1, La Gloria	7,233	Lissie	Vicksburg
61	Jim Wells	Stoltze No. 1, La Gloria	7,347	Lissie	Vicksburg
62	Jim Wells	McNeil No. 1, Wade City area	5,410	Lissie	Vicksburg
63	Jim Wells	Perales No. 2, Ben Bolt	5,470	Lissie	Vicksburg
64	Jim Wells	A. P. Garcia No. 1, M. Barrerra survey	6,862	Lissie	Yegua
65	Jim Wells	Reynolds & Richardson No. 1, Mag. City	5,714	Lissie	Frio
66	Kleburg	State No. 1, blk. 155, Bird Island, Laguna Madre	7,320	Submerged	Frio
67	Nueces	La Prelle No. 1, Roberts & White subd.	7,440	Beaumont	Frio
68	Nueces	Minnie Bock No. 1, sec. 55, Herrerra grant	4,051	Beaumont	Catahoula
69	Nueces	Potter No. 1, Blk. 10, Paul's subd.	7,089	Beaumont	Frio
70	Nueces	Minnie Brown No. 1, Agua Dulce	13,728	Beaumont	Yegua
71	Nueces	King No. 1*A*, Richard King	5,419	Beaumont	Frio
72	Nueces	King No. 16, Richard King	6,143	Beaumont	Vicksburg
73	Nueces	King No. 2*B*, Richard King	5,419	Beaumont	Frio
74	Nueces	Richardson No. 1, So. Clara Driscoll	7,560	Beaumont	Vicksburg
75	Nueces	Clara Driscoll No. 1*B*, Clara Driscoll field	8,194	Beaumont	Vicksburg
76	Nueces	Martin No. 1, So. Clara Driscoll	6,701	Beaumont	Frio
77	Nueces	W. H. Wallace No. 1, Agua Dulce	7,250	Beaumont	Frio
78	Nueces	Ingram No. 3, Agua Dulce	7,398	Beaumont	Vicksburg
79	Nueces	J. J. Elliff No. 2, No. Agua Dulce	5,135	Beaumont	Frio
80	Nueces	La Prelle No. 4*A*, North Luby	5,085	Beaumont	Frio
81	Nueces	Richard King 4*A*, Richard King	5,381	Beaumont	Frio
82	Nueces	Thompson & Bland No. 1, Riverside	5,280	Beaumont	Frio
83	Nueces	Harper No. 1, No. Agua Dulce	5,762	Beaumont	Frio
84	Nueces	E. C. Wilson No. 2, Riverside area	5,037	Beaumont	Frio
85	San Patricio	Pearson No. 1, blk. 29, Paul's subd.	6,348	Beaumont	Jackson
86	San Patricio	M. C. Smith No. 1, Juan-Hart survey	7,295	Beaumont	Frio
87	San Patricio	Blumberg No. 1, East Mathis	6,015	Beaumont	Jackson
88	San Patricio	Brooks No. 3, East White Point	8,383	Beaumont	Vicksburg
89	San Patricio	Baldwin No. 5*A*, East White Point	5,737	Beaumont	Frio
90	San Patricio	Dunn No. 1, White Point	5,676	Beaumont	Frio
91	San Patricio	A. A. Galler No. 1, East Plymouth	6,036	Beaumont	Frio
92	San Patricio	Welder No. 6, Angelita	7,042	Beaumont	Frio
93	San Patricio	Morgan & Meginnis No. 1, McCampbell	7,141	Alluvium	Frio
94	San Patricio	Rachal No. 21, East White Point	5,683	Beaumont	Frio
95	San Patricio	L. Phillips No. 1, East White Point	6,007	Beaumont	Frio
96	San Patricio	Sherwood No. 1, McCampbell area	9,074	Alluvium	Frio

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
57	Graham & Mosser	75		3/32	500	2,750	New 4800-ft. Frio sand, Reynolds
58	Rand Morgan	130		1/8	2,050	1,475	New 5100-ft. Vicksburg sand, Reynolds
59	Transwestern Oil Co.	65	Gas	1/4	1,100	1,600	New 5400-ft. Frio sand, East Premont
60	Magnolia Petr. Co.	54 (heading)		Open tubing			New 7200-ft. Vicksburg sand, La Gloria
61	Magnolia Petr. Co.	50	10	5/16	3,000	3,150	New 7000-ft. Frio sand, La Gloria
62	Rowe & De Lange	10	2	1/8	1,900 (working)		New 4700-ft. Frio sand & ext. Wade City
63	Mosser et al.	70		3/32	725	200	New 5400-ft. Vicksburg sand, Ben Bolt
64	Texas Gulf Producing						Dry deep test
65	Meyer & Simon	259		7/32	1,050	750	New 5700-ft. Frio sand, Magnolia City
66	Pure Oil Co.	68		11/64	2,500	2,325	Oil production Bird Island
67	Seaboard Oil Co.	173		1/8	1,575	1,275	Discovery North Luby field
68	Texas Conservative	121		1/8	1,600	1,240	Discovery Minnie Bock field
69	Shield Oil Co.	75		5/64	650	950	Discovery Robston field
70	Union Producing Co.		15				Deepest well South Texas
71	Southern Minerals Co.	671		1/4	2,075	1,250	New 5400-ft. Frio sand, Richard King
72	Southern Minerals Co.	38		1/4	1,425	550	New 6100-ft. Vicksburg sand, Richard King
73	Southern Minerals Co.	157		5/32	1,150	650	New 5200-ft. Frio sand, Richard King
74	Wellington Oil Co.	151		1/4	475	200	New 6500-ft. Frio sand, Clara Driscoll
75	Wellington Oil Co.	113			(Pumping)		New 5300-ft. Frio sand and ext. Clara Driscoll
76	Wellington Oil Co.	750					New 5200-ft. Frio sand and ext. So. Clara Driscoll
77	Union Producing Co.	100	10	1/4	2,700	2,650	New 6600-ft. Frio sand, Agua Dulce
78	Process Oil Co.	100	25				New 6900-ft. Frio sand, Agua Dulce
79	Union Producing Co.	100	10				New 5000-ft. Frio sand, No. Agua Dulce
80	Seaboard Oil Co.	155		1/8	450	450	New 5000-ft. Het. sand, North Luby
81	Southern Minerals Co.	250		3/16	1,000	600	North ext. Richard King
82	Stanolind O. & G. Co.	30	20	1/8	1,725	2,025	Southeast ext. Riverside
83	Union Producing Co.	106		(Jetting)			New 5500-ft. Frio sand, No. Agua Dulce
84	Seaboard Oil Co.	88		1/8	1,600	1,175	Oil production and West ext. Riverside
85	Seaboard Oil Co.	54		1/8	700	325	Discovery East Mathis field
86	Seaboard Oil Co.	45.6	Gas	3/16	2,650 (working)		Discovery Odem field
87	Seaboard Oil Co.		4.5	3/8	1,600	1,450	New 4400-ft. Frio sand, East Mathis
88	Plymouth Oil Co.		5	1/8	550	500	New 4000-ft. Catahoula sand, East White Point
89	Houston Oil Co.		10	1/8	550	500	New 2500-ft. Miocene sand, East White Point
90	Easterwood & Cage	154		1/8	650	500	New 5600-ft. Frio sand, White Point
91	Republic Nat. Gas		10	1/8	1,850	1,800	New 5100-ft. Frio sand, East Plymouth
92	Wellington Oil Co.	32			(Pumping)		New 6200-ft. Frio sand, Angelita
93	R. B. Byrant	535		3/16	750	600	Extension McCampbell
94	Republic Nat. Gas	102					Ext. East White Point
95	Republic Nat. Gas		20	1/8	1,650	1,450	NE. ext. East White Point
96	Richardson Petr. Co.						Dry deep test

	In Proven Fields	Rank Wildcats
Number of oil wells completed during 1939	1215*	29*
Number of gas wells completed during 1939	50	0
Number of dry holes completed during 1939	252	257

* Including wells producing distillate and gas.

from 2014 to 2035 ft. The well had drilled to 3309 ft. and tested all the usual Mirando sand zones.

New Sands in Existing Fields, Duval County

Longhorn Field, Second Sand.—Longhorn Drilling Company's Miller No. 2*A* was completed Feb. 15 in a Jackson (Cole) sand from 4033 to 4038 ft. for a flow of 105 bbl. of 44° gravity oil, through ⅛-in. choke under 575 lb. tubing pressure and 740 lb. casing pressure. Several wells cored this sand but Miller No. 2*A* was the first to produce from it.

Tesoro Field, Second Sand.—A fault of about 300 ft. displacement was considered proved by the completion of Magnolia Petroleum Company's Spence No. 2 as a gasser from perforations at 4840 to 4848 ft. in Pettus sand. The offset well had found this sand at approximately 5100 feet.

Seven Sisters Field, Sixth Sand.—Wellington Oil Company's Welder No. 2*G*, on the western side of the Seven Sisters structure, produced 10,000,000 cu. ft. of gas daily from perforations at 3055 to 3063 ft. in a Yegua sand at 3037 to 3070½ feet.

Important Extensions to Established Areas, Duval County

Hoffman Field.—The Hoffman field was extended 2 miles southwest by Magnolia Petroleum Company's A. Weil No. 1, sec. 113, which flowed 6,900,000 cu. ft. of gas with 890 lb. rock pressure from perforations at 2651 to 2661 ft. in Government Wells sand at 2644 to 2661 ft. The Company's Weil No. 2, 1467 ft. northeast of No. 1, was completed in Loma Novia sand at 2806 to 2836 ft. and jetted 42 bbl. of oil daily through ½-in. choke with 200 lb. pressure on casing. Both wells were completed in November.

JIM HOGG COUNTY, LAREDO DISTRICT

Holland-Hebbronville Field.—The Holland-Hebbronville field was brought in on Nov. 15 by Mayfair Oil Company's Isabel Guiterrez No. 1, El Peyote grant, from Loma Novia sand at 3217 to 3223 ft. On completion the well pumped 35 bbl. of 32.3° gravity oil daily.

Important Extensions to Established Areas, Jim Hogg County

Colorado Field.—Humble Oil and Refining Company's King Ranch Colorado No. 1, sec. 42, was completed as a one-mile north extension to the Colorado field when it flowed 435 bbl. of 42.6° gravity oil per day from Cockfield sand at 3032 to 3041 ft.; production was through ⅜-in. choke with 225 lb. tubing pressure and 700 lb. casing pressure.

MCMULLEN COUNTY, LAREDO DISTRICT

Important Extensions to Established Areas, McMullen County

South Calliham Field.—Edwin M. Jones' Ezzell No. 96, sec. 4, produced 25 bbl. of oil daily on pump from perforations at 1056 to 1060 ft.

TABLE 3.—*Deep Wells Drilled during* 1939

County	Location	Company and Well	Depth, Ft.	Last Formation	Results
LAREDO DISTRICT, WELLS DRILLED TO 6000 FEET AND BELOW					
Duval........	Wildcat, Conception grant	Glassock-Garcia No. 1	6,517	Yegua	Dry
Duval........	Wildcat, San Andres grant	Howell & Cunningham Parr No. 1	6,542	Yegua	Dry
Duval........	Wildcat, survey 14	Cunningham-Lopez No. 1	6,505	Yegua	Dry
Duval........	Sejita	Standard of Texas Casey No. 1	6,747	Yegua	Oil and gas
Duval........	Wildcat, Benavides area	Parr Drilling Co. Villareal No. 1	6,015	Yegua	Dry
Duval........	Sweden	Gravis & Doran-Parr No. 1	6,281	Yegua	Dry
Duval........	San Diego area, wildcat	Cullen & Mayo Hoffman No. 1	6,135	Yegua	Dry
Duval........	Wildcat, 4 mi. south Realitos	Luling Oil Co. Dimmitt No. 1	6,012	Yegua	Dry
Duval........	Wildcat, 6 mi. NW. Conception	Magnolia Petroleum Co. Denman No. 1	6,135	Yegua	Dry
Duval........	Wildcat, sec. 378	Texas Gulf Prod. Co. Dunn No. 1	6,022	Yegua	Dry
Duval........	Wildcat, San Andres grant	J. Gravis Parr No. 1	6,143	Yegua	Dry
Duval........	Wildcat, R. Fletcher survey	J. Gravis Vaello No. 1	6,023	Yegua	Dry
Duval........	Wildcat, survey 544	Rowan & Hope Lopez No. 1	6,516	Yegua	Dry
Duval........	Benavides	Hiawatha Oil Co. Parr No. 27	6,206	Yegua	Dry
Duval........	Longhorn	Hiawatha Oil Co. Denham No. 5	6,011	Yegua	Dry
Jim Hogg....	Wildcat, 12 miles south Hebbronville	Humble Oil & Ref. Co. Mestena No. 1	7,01	Mt. Selman	Dry
Jim Hogg.....	Wildcat, Palo Blanco grant	Humble Oil & Ref. Co. Mestena No. 2	6,495	Mt. Selman	Dry
Starr.........	Barbacoas area	Magnolia Petroleum Co. Garcia No. 1	6,567	Yegua	Dry
Starr.........	South La Reforma	Magnolia Petroleum Co. Guerra No. 2	6,566	Vicksburg	Oil and gas
Starr.........	Santo Domingo area	Argo Oil Corp., Bennett & Roos No. 1	6,005	Yegua	Dry
Webb........	Cole-Bruni	Tide Water Assoc. Oil Co. A. M. Bruni No. 7	8,959	Wilcox	Wilcox Show. Plug back
SOUTH CORPUS CHRISTI DISTRICT, WELLS DRILLED TO 7500 FEET AND BELOW					
Brooks.......	Wildcat, Gyp-Hill area	Southern Minerals Procter No. 1	7,726	Vicksburg	Dry
Cameron.....	Wildcat, San Martin grant	Sal-Vieja Oil Corp. Newberry No. 1	7,585	Frio	Dry
Cameron.....	Wildcat, San Martin grant	Sal-Vieja Oil Corp. Newberry No. 2	8,445	Frio	Dry
Cameron.....	Wildcat, San Martin grant	Sal-Vieja & Pure Oil Co. Newberry No. 3	8,168	Frio	Dry
Hidalgo......	La Blanca	Pantano Oil Co. Harding No. 1	8,074	Frio	Gas and distillate
Hidalgo......	Wildcat	Shary-Maddox. Neal No. 1	7,506	Frio	Dry

in the Government Wells sand, to extend the South Calliham field ¾ mile southwest.

Starr County, Laredo District

North Ricaby Field.—H. C. Bishop's and J. O. Moss et al.'s S. B. Ricaby No. 1, 3325 ft. north of Ricaby field, was completed on May 22

Table 3.—(*Continued*)

County	Location	Company and Well	Depth, Ft.	Last Formation	Results
South Corpus Christi District, Wells Drilled to 7500 Feet and Below					
Hidalgo......	Wildcat, San Ramon grant	Rowan & Hope Bazan No. 1	7,508	Frio	Dry
Hidalgo......	Wildcat, Mestenas grant	Pan-American Vina No. 1	8,123	Frio	Dry
Jim Wells.....	Blucher	Shell Von Blucher No. 1	7,845	Vicksburg	Gas and distillate
Jim Wells.....	La Gloria	Magnolia Petroleum Co. Sam Maun No. 1	7,545	Vicksburg	Gas and distillate
Jim Wells.....	Premont townsite (1 mi. W.)	Premont Oil Co. Hewitt No. 1	7,507	Jackson	Dry
Jim Wells.....	Blucher	Shell Von Blucher No. 2	8,004	Vicksburg	Dry
Kenedy......	Wildcat, 13.8 mi. SE. Rivery Beach	Humble Oil & Ref. Co. Kenedy Ranch No. 1	7,920	Frio	Dry
Kenedy......	Wildcat, Pensacola grant	Humble Oil & Ref. Co. Kenedy Ranch No. 2	7,818	Frio	Dry
Kenedy......	Wildcat, Salinas survey	Humble Oil & Ref. Co. Kenedy Ranch No. 3	7,706	Frio	Dry
Kleburg......	Bird Island	Pure Oil Co. State No. 1	8,403	Frio	Dry
Nueces.......	Agua Dulce	Union Prod. Co. Minnie Brown No. 1	13,728	Yegua	Gas
Nueces.......	Saxet	Richardson Petr. Co. Harrell No. 3	10,042	Vicksburg	Dry
Nueces.......	Saxet	Hiawatha Oil Co. Smith No. 6*B*	9,880	Vicksburg	Dry
Nueces.......	Wildcat, sec. 1	Graham Taylor No. 1	7,522	Vicksburg	Dry
Nueces.......	Wildcat, sec. 175	Renwar & Fox Knight No. 1	7,508	Vicksburg	Dry
Nueces.......	Wildcat, SE. Corpus Christi	Mills Bennett Poenisch No. 1	7,508	Frio	Dry
Nueces.......	Riverside	Shell Griffin No. 1	7,510	Vicksburg	Dry
Nueces.......	South Clara Driscoll	Wellington Oil Co. Richardson No. 1	7,560	Vicksburg	Oil
Nueces.......	Wildcat, sec. 30	O. W. Killam Smith No. 1	7,512	Vicksburg	Dry
Nueces.......	Wildcat	Renwar Oil Co. Eschberger No. 1	7,510	Vicksburg	Dry
Nueces.......	Clara Driscoll	Wellington Oil Co. Driscoll 1*B*	8,194	Vicksburg	Oil
Nueces.......	Saxet	Hiawatha Oil Co. Griffith No. 4	7,741	Frio	Oil
San Patricio..	McCampbell	Richardson Petr. Co. Sherwood No. 1	9,074	Frio	Dry
San Patricio..	East White Point	Plymouth Oil Co. Brooks No. 3	8,383	Vicksburg	Gas
San Patricio..	McCampbell	Bay-Tex-Oil Co. Lish Cralle No. 1	7,650	Frio	Oil
Willacy.......	Wildcat, San Juan de Carricitos grant	Midwest Oil Co. Dayton No. 1	9,005	Frio	Dry
Willacy	La Sal Vieja	Andrade Yturria No. 1	7,714	Frio	Dry

TABLE 4.—*Total Number of Wells Drilled in South Texas Fields during* 1939

LAREDO DISTRICT			
Field	Distillate or Oil	Gas	Dry
Duval County			
Benavides	21	1	3
Casa Blanca	9	0	4
North Casa Blanca	9	0	3
Cedro Hill	19	2	1
Chiltipin	2	1	0
Colmena	0	0	1
Conoco Driscoll	13	0	0
Eagle Hill	5	2	4
El Mesquite	0	0	1
Fitzsimmons	38	0	2
Government Wells	1	3	1
Hoffman	64	5	8
Kohler	0	1	1
Loma Novia	0	0	3
Loma Vista	0	0	1
Longhorn	40	0	3
Lundell	20	3	0
Muralla	2	0	1
Palangana	0	0	1
Peters	1	0	0
Piedre Lumbre	52	0	1
Piedras Pintas	4	0	1
Rancho Solo	15	2	9
Sejita	1	0	0
Seven Sisters	4	2	0
Southland	4	0	2
Sweden	0	0	1
Tarancahuas	1	0	0
Tesoro	3	1	2
Total	328	23	54
Jim Hogg County			
Colorado	15	0	2
Holland-Hebbronville	1	0	0
Kelsey	11	0	1
Randado	0	0	2
Total	27	0	5
McMullen County			
Calliham[1]	5	0	6
Campana	0	0	3
Ezzell	47	0	16[2]
Munson	8	0	0
Rhode	0	0	1
San Jose	0	0	3
Total	60	0	29
Starr County			
Barbacoas	0	0	1
El-Tanque (South Ricaby)	5	0	5
Guerra	1	0	0
South La Reforma	1	0	0
Los Olmos	0	0	1
Ricaby[3]	6	0	3
Rincon	3	0	8
North Rincon	1	0	1
Santo Domingo	0	0	1
Seabury	1	0	1
Sun	15	0	3
Young (Charco-Blanco)	0	0	1
Total	33	0	25
Webb County			
Adami	19	0	0
Carolina-Texas	0	1	1
Cole O'Hern	1	0	0
Cole West	5	0	3
Killam	9	0	1
North Killam	5	0	6
Laurel	0	0	1
Mirando City	0	0	1
Oilton	0	0	1
Volpe	12	0	6
Total	51	1	20

Laredo District continued at foot of next column.

SOUTH CORPUS CHRISTI DISTRICT			
Field	Distillate or Oil	Gas	Dry
Brooks County			
Alta Mesa	0	0	2
Kelsey	38	0	4
Total	38	0	6
Hidalgo County			
LaBlanca	1	0	0
Sam Fordyce	17	0	5
Sullivan City	5	4	2
Total	23	4	7
Jim Wells County			
Alfred[4]	4	0	3
Alice	15	0	4
East Alice (Tom-Graham)	38	1	3
Armagosa	0	0	2
Bandera	0	0	2
Ben Bolt	23	1	2
Blucher	1	0	1
Camada	2	0	1
Clark-Muil	5	2	1
La Gloria	4	0	0
Magnolia City	2	0	3
Premont	1	0	0
East Premont	3	0	0
Reynolds	29	0	9
Wade City	2	0	0
Total	129	4	31
Kleburg County			
Bird Island	1	0	1
Total	1	0	1
Nueces County			
Agua Dulce	23	5	4
North Agua Dulce	5	0	2
Clara Driscoll	27	2	6
South Clara Driscoll	10	0	2
Flour Bluff	3	0	0
London	0	0	1
Luby	45	0	0
North Luby	2	0	3
Minnie Bock	23	0	3
Richard-King	18	1	2
Riverside	3	0	6
Robston	1	0	0
Saxet	31	3	6
Stratton	2	0	0
Turkey Creek	6	1	2
Total	199	12	37
San Patricio County			
Angelita	1	0	0
Aransas Pass (McCampbell[5])	115	0	5
East Mathis	2	0	0
Odem	1	0	0
Plymouth	15	0	0
East Plymouth	0	1	1
Taft	0	0	1
White Point	2	0	1
East White Point	128	3	5
Total	264	4	13
Grand total, South Corpus Christi District	654	24	95
Grand total for South Texas fields, 1939	1,242	50	252

LAREDO DISTRICT (CONTINUED)			
Zapata County			
Charco Redondo	1	0	1
Comitas	15	0	7
Escobas	14	0	4
Jennings	3	0	1
Lopena	0	0	2
Mirando Valley	56	2	9
Total	89	2	24
Grand total, Laredo District	588	26	157

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[1] Includes South Calliham.

[2] Also one dry hole in Live Oak County portion of Ezzell field.

[3] Includes North Ricaby.

[4] Includes West Alfred.

[5] Also, 27 oil wells were completed in the Aransas County portion of the Aransas Pass field.

pumping 120 bbl. of 21° gravity oil from Frio sand at 1294 to 1305 ft. On Aug. 23, a second sand for this field was found by Howard Bass' Lester No. 1, which pumped 100 bbl. of 21.5° gravity oil daily from Frio sand at 1432 to 1437 feet.

North Rincon Field.—The North Rincon field was discovered by Transwestern Oil Co. and Rowan and Hope's W. I. Cameron No. 1, sec. 228, which was completed on May 23 in Vicksburg sand at 4154 to 4173 ft., through perforations at 4160 to 4170 ft. The well flowed 145 bbl. of 41.4° gravity oil daily through $^{11}/_{64}$-in. choke under 365 lb. tubing pressure and 610 lb. casing pressure.

South LaReforma Field.—Magnolia Petroleum Company's Guerra Fee No. 2*F*, Farrias grant, about 3½ miles southwest of LaReforma production, on Aug. 21 flowed 80 bbl. of 51.5° gravity distillate and 4,360,000 cu. ft. of gas through $^{9}/_{64}$-in. choke with 2050 lb. pressure on tubing and 2260 lb. on casing from perforations at 5810 to 5818 ft. in a Frio sand at 5798 to 5832 ft. Total depth was 6566 feet.

Seabury Field.—This field, about 3 miles northwest of Rio Grande City, was opened on Dec. 8 by Clopton and Mitchell's Seabury No. 1, Porcion 80, which produced 25 bbl. of 22.6° gravity oil per day from Frio sand through perforations at 1328 to 1333 feet.

New Sands in Existing Fields, Starr County

Sun Field.—A fourth sand in the Sun field was found on Jan. 11 through the completion of Sun Oil Company's McKinney No. 3, which

TABLE 5.—*Rank Wildcats (Field Discoveries) Completed during* 1939

LAREDO DISTRICT					SOUTH CORPUS CHRISTI DISTRICT				
County	Oil	Distillate and Gas	Gas	Dry Holes	County	Oil	Distillate and Gas	Gas	Dry Holes
Duval	5	1	0	61	Brooks	0	0	0	3
Jim Hogg	1	0	0	12	Cameron	0	0	0	5
McMullen	0	0	0	37	Hidalgo	1	0	0	3
Starr	3	1	0	35	Jim Wells	5	4	0	23
Webb	2	0	0	34	Kenedy	0	0	0	3
Zapata	1	0	0	10	Kleburg	0	0	0	3
					Nueces	3	0	0	17
Total	12	2	0	189	San Patricio	1	1	0	10
Average, 1 producer for every 14½ rank wildcats.					Willacy	0	0	0	1
					Total	10	5	0	68
					Average, 1 producer for every 5½ rank wildcats.				
Grand total South Texas						22	7	0	257

flowed 119 bbl. of 46° gravity oil through ⅛-in. choke under 750 lb. tubing pressure and 650 lb. casing pressure, from Frio sand at 4652 to 4673 ft. Casing was perforated at 4660 to 4670 ft. Sun Oil Company's McKinney No. 4 was completed on Feb. 21 from a fifth Frio sand at 4610 to 4623 ft. The well flowed 5,000,000 cu. ft. of gas and 25 bbl. of distillate daily. On March 22, Sun Oil Company's Olivarez No. 2 flowed 40 bbl. of 52° gravity distillate and much gas daily through perforations at 4129 to 4135 ft. in a sixth Frio sand at 4111 to 4142 ft. Flow was through ⅛-in. choke under 1800 lb. working pressure on tubing. On April 12, the same company's Speer No. 1 flowed 208 bbl. of 46° gravity oil from a seventh Frio sand at 4908 to 4972 ft.; flow was through 3/16-in. choke under 800 lb. tubing pressure and 1475 lb. casing pressure.

Important Extensions to Established Areas, Starr County

Sun Field.—Sun Oil Company's I. V. Montalvo et al. No. 1 flowed 78 bbl. oil daily from perforations at 4855 to 4868 in Frio sand to extend the Sun field 1½ miles northwest. Production was through 3/16-in. choke under 175 lb. tubing pressure and 600 lb. casing pressure. Total depth was 5134 feet.

Rincon Field.—The Rincon field was given two important extensions during the year. The first was by Davenport and Hoffer's Dallas Joint Stock Land Bank No. 1, sec. 226, two miles north of the field; this well flowed 22 bbl. of 58° gravity dark distillate and an estimated 4,000,000 cu. ft. of gas in 10 hr. through ¼-in. choke under 1350 lb. tubing pressure from perforations in a Vicksburg sand at 4284 to 4294 ft. The second extension, 18,500 ft. southwest of the field, was completed flowing 140 bbl. of oil through 5/32-in. choke with 850 lb. tubing pressure and 1450 lb. casing pressure from a Vicksburg sand at 4170 to 4190 ft. This may be a new producing level. This second well, W. R. Davis and Company's T. B. Slick No. 1, sec. 528, was bottomed at 4320 feet.

TABLE 6.—*Texas Railroad Commission Production Schedule for* 1939

Month	Number of Producing Days	Number of Shut-in Days	Month	Number of Producing Days	Number of Shut-in Days
January	23	8	August	12	19
February	20	8	September	21	9
March	23	8	October	20	11
April	25	5	November	19	11
May	25	6	December	19	12
June	22	8			
July	23	8	Total	252	113

WEBB COUNTY, LAREDO DISTRICT

Adami Field.—Gordon W. Johnson et al.'s Mabel Adami No. 1, in the northeast corner of the county, sec. 345, pumped 35 bbl. of 20.5° gravity crude in 24 hr. from Mirando sand at 992 to 999 ft. on May 15.

Volpe Field.—This field was brought in by Magnolia Petroleum Company's Benavides No. 5*B*, sec. 695, 2½ miles east of West Cole, on June 20, when it pumped 90 bbl. of 22.5° gravity oil from Mirando sand at 2458 to 2466 feet.

Important Extensions to Established Areas, Webb County

West Cole.—V. G. Schimmel's Benavides No. 1, sec. 693, between the two oil-producing sections of the West Cole field, pumped 96 bbl. of oil daily from Mirando sand at 2336 to 2350 feet.

ZAPATA COUNTY, LAREDO DISTRICT

South Mirando Valley Field.—Interstate Minerals and Edgar B. Younger's R. Lopez No. 1, sec. 113, discovered the South Mirando Valley field on April 15, when it produced gas along with about 35 bbl. of 21° gravity crude from Mirando sand at 1791 to 1798 ft. The company's Lopez No. 4, which flowed 42 bbl. of 20.2° gravity crude in 12 hr. through 5⁄16-in. choke under 330 lb. tubing pressure and 425 lb. casing pressure, was the first good oil producer in the field. It found the sand from 1802 to 1810 feet.

BROOKS COUNTY, SOUTH CORPUS CHRISTI DISTRICT

New Sands in Existing Fields, Brooks County

Kelsey Field.—Humble Oil and Refining Company's McGill No. 5 discovered a second sand for the Kelsey field on April 4, when it was completed in a Government Wells (Jackson) sand through perforations at 6099 to 6107 ft. The well flowed 63 bbl. of 42° gravity oil through 3⁄16-in. choke under 1050 lb. tubing pressure and 1400 lb. casing pressure. The Frio sand from 4655 to 4662 ft. showed gas. Total depth was 6407 feet.

HIDALGO COUNTY, SOUTH CORPUS CHRISTI DISTRICT

Sullivan City Field.—On the downthrow side of the Sam Fordyce, and ½ mile north of the field, Fohs Oil Company's Sullivan No. 1, Porcion 39, was completed on March 20 as the first well productive on this side of the fault. This area has been given the name Sullivan City field, instead of being regarded as an extension to the Sam Fordyce field. The well produced 76 bbl. of 24.8° gravity oil along with gas daily through 5⁄32-in. choke, under pressures of 1100 lb. on tubing and 1450 lb. on casing;

perforations were made from 3428 to 3436 ft. in Frio sand found from 3414 to 3437 ft. This well is 825 ft. northeast of Phillips Petroleum Company's Flores No. 1, which last year drilled to 9708 ft. after cutting the fault between 4200 to 4300 ft. Flores No. 1 was plugged back and completed at 5840 to 5900 ft. in the Jackson, which it topped at 4375 ft., after finding practically no Vicksburg; this year it was further plugged back and completed in the Fohs Frio sand as the second oil producer in this area. It flowed 108 bbl. of 25.6° gravity oil daily through ⅛-in. choke, under 925 lb. tubing pressure. The fault separating the Sam Fordyce and Sullivan City fields trends in a northwest-southeast direction.

John Messenger et al.'s V. Garza Chapa No. 1, 3000 ft. northeast of the Fohs well, opened a second Frio sand on May 4, when it flowed 3,000,000 cu. ft. of gas daily through 11⁄64-in. choke under 1375 lb. tubing pressure and 1500 lb. casing pressure; perforations were made from 3979½ to 3981½ ft. in sand found from 3936 to 3983 feet.

New Sands in Existing Fields, Hidalgo County

LaBlanca Field.—A third sand was discovered in the LaBlanca field by Pantano Oil Company's McDougall No. 1, which was recompleted on Feb. 21 for a flow of 100 bbl. of 48° gravity distillate along with considerable gas from perforations at 7450 to 7480 ft., in Frio sand, through 7⁄16-in. choke, under 2700 lb. working pressure. Pantano Oil Company's R. E. Harding No. 1 was brought in on Aug. 4, flowing 80 bbl. of 55° gravity distillate with much gas from a fourth Frio sand. Production was from perforations at 8035 to 8074 ft., through ⅜-in. choke, under 3850 lb. tubing pressure. Residue gas from both these new sands is being returned to the 7800-ft. sand, which had been seriously depleted by a blowout well.

JIM WELLS COUNTY, SOUTH CORPUS CHRISTI DISTRICT

Blucher Field.—The Blucher field was opened on Feb. 3 by Shell Petroleum Company's Von Blucher No. 1, Best Survey. It produced 32 bbl. of 54° gravity distillate and 1,300,000 cu. ft. of gas daily from perforations at 7555 to 7560 ft. in Vicksburg sand found at 7500 to 7560 ft.; flow was through 3⁄64-in. choke under 3600 lb. tubing pressure.

Clark-Muil Field.—Gravis and Doran discovered the Clark-Muil field on March 23, when Frances Clark No. 1, Los Prenos grant, about 2 miles east of East Alice field, flowed 16 bbl. of 60° gravity distillate and much gas from perforations at 4795 to 4818 ft. in Frio sand from 4795 to 4835 ft. Production was obtained through 3⁄32 to 9⁄64-in. chokes under pressures of 1400 lb. on tubing and 1450 lb. on casing. A Vicksburg sand at 5326 to 5330 ft. was proven by Gravis and Doran's Muil No. 1, one mile south of the No. 1 Frances Clark. It flowed 150 bbl.

of 42° gravity oil per day through ⅛-in. choke, under 900 lb. tubing pressure and 1325 lb. casing pressure.

La Gloria Field.—Magnolia Petroleum Company's Sam Maun No. 1, La Blanca grant, flowed 165 bbl. of 60° gravity distillate with 5,646,000 cu. ft. of gas on March 23 to discover the La Gloria field. The well was plugged back from total depth of 7545 ft. and completed from perforations at 6560 to 6570 ft., in Frio sand at 6533 to 6598 ft., through 5⁄16-in. choke under 2000 lb. tubing pressure and 2170 lb. casing pressure. In September, Magnolia Petroleum Company's Dale O. Maun No. 1, a mile west of the discovery, headed 54 bbl. of 25° gravity crude oil daily through open tubing from perforations at 7219 to 7232 feet in a Vicksburg sand; this was the field's first crude production. The same company's E. H. Stoltze No. 1 flowed 50 bbl. of distillate along with much gas from a Frio sand at 6998 to 7011 ft., through perforations at 7000 to 7010 ft. Flow was under 3150 lb. tubing pressure and 3000 lb. casing pressure.

West Alfred Field.—Lewis Production Co. and Ike Howeth's Adams No. 1, sec. 122, about 1½ miles southwest of the Alfred field, flowed 135 bbl. of 45.2° gravity oil on April 14 from 4661 to 4674 ft. in a Vicksburg sand. Flow was through 3⁄16-in. choke under 835 lb. tubing pressure and 1250 lb. casing pressure.

Magnolia City Field.—F. A. Gillespie and Son's Shear No. 1, A. B. and M. Survey, about 7½ miles southeast of Alice, flowed 145 bbl. of 43.8° gravity oil on April 30. Perforations were made from 5438 to 5445 ft. in a Frio sand from 5436 to 5446 ft. and production was through ⅛-in. choke under 1450 lb. tubing pressure and 2000 lb. casing pressure. Total depth was 6592 ft. A new sand was found in December by Meyer and Simon's Reynolds and Richardson No. 1, which flowed 259 bbl. of 45° gravity oil from perforations at 5705 to 5709 ft. in a Frio sand from 5704 to 5714 ft. through 7⁄32-in. choke, under 750 lb. tubing pressure and 1050 lb. casing pressure. This well, 1600 feet northwest of the discovery, cored the discovery sand at 5437 to 5439 feet.

Ben Bolt Field.—On May 24, Bridwell Oil Company's W. W. Smith No. 1, La Trinidad grant, 1½ miles southwest of Ben Bolt, was completed from perforations at 5242½ to 5246½ ft. in a Vicksburg sand at 5231 to 5251 ft. The well flowed 196 bbl. of 41.5° gravity oil through ⅛-in. choke under 875 lb. tubing pressure and 1000 lb. casing pressure. A new sand was discovered in August by H. J. Mosser's E. Perales No. 1, which flowed gas from perforations at 5383 to 5386 ft. in Vicksburg sand from 5370 to 5390 ft. Shut-in pressure was 2100 lb. In October, Mosser's Perales No. 2 flowed 70 bbl. of 42.5° gravity oil from perforations at 5414 to 5418 ft. in a third Vicksburg sand from 5413 to 5333 ft. Flow was through 3⁄32-in. choke under 200 lb. tubing pressure and 725 lb casing pressure.

Camada Field.—Parr Drilling Company's Mrs. W. K. Hoffman No. 1, sec. 8, in the Springfield townsite, flowed 70 bbl. of 46.4° gravity oil through 3⁄32-in. choke under 850 lb. tubing pressure and 1300 lb. casing pressure, on May 28. Production was from perforations at 5628 to 5633 ft. in a Hockleyensis sand from 5627 to 5637 feet.

Reynolds Field.—Texas Gulf Producing Company's E. E. Miller No. 1, Agua Dulce grant, 3 miles northeast of Alice, was completed on June 24 for a flow of 50 bbl. of 35.5° gravity oil with much gas. Casing was perforated from 5143 to 5149 ft. in a Frio sand found at 5101 to 5155 ft., and flow was through 5⁄64-in. choke under 1850 lb. tubing pressure and 1950 lb. casing pressure. In August, Rand Morgan's Fee No. 2*F* found a new Frio sand from 5111 to 5116 ft., where it was completed for a flow of 130 bbl. of 41° gravity oil through 1⁄8-in. choke under pressures of 1475 lb. on tubing and 2050 lb. on casing. The discovery sand is about 40 ft. lower structurally. A third Frio sand was proved productive in August, through the completion of Tom Graham and Harry Mosser's Mosser No. 4*A*, which flowed 75 bbl. of 31° gravity oil through 3⁄32-in. choke under 2750 lb. tubing pressure and 500 lb. casing pressure from perforations at 4817 to 4821 feet.

Wade City Field.—J. R. Hunter and W. R. Quinn's M. and F. Pundt No. 1, Poitevent Survey, about 2 miles northwest of Orange Grove, flowed 30 bbl. of 47.7° gravity distillate and 3,000,000 cu. ft. of gas daily from perforations at 4809 to 4813 ft. in Frio sand. This well, completed July 12, flowed through 7⁄64-in. choke under 1850 lb. tubing pressure and 1900 lb. casing pressure. Another sand was found by Rowe and Delange's McNeil No. 1, a mile southeast of the discovery, when it produced 10 bbl. of 54° gravity distillate and 2,000,000 cu. ft. of gas from Frio sand through perforations from 4788 to 4791 ft. in November. Flow was through 1⁄8-in. choke under 1900 lb. working pressure.

KLEBURG COUNTY, SOUTH CORPUS CHRISTI DISTRICT

Important Extensions to Established Areas, Kleburg County

Bird Island Field.—Pure Oil Company's State of Texas No. 1, block 155, 3500 ft. northwest of the discovery well, was completed for a flow of 68 bbl. of 44° gravity oil daily from perforations at 7235 to 7247 ft. in the Frio sand, which produced distillate and gas in the discovery well. Flow was through 11⁄64-in. choke under 2500 lb. casing pressure and 2325 lb. tubing pressure.

NUECES COUNTY, SOUTH CORPUS CHRISTI DISTRICT

North Luby Field.—Seaboard Oil Corporation's John LaPrelle No. 1*A*, block 9, Roberts and White Survey, nearly 2 miles north of Luby production, drilled to 7440 ft., plugged back and perforated from 4347 to 4354 ft.

in a Catahoula sand from 4347 to 4361 ft., and obtained a flow of 173 bbl. of 51° gravity oil through ⅛-in. choke under 1275 lb. tubing pressure and 1575 lb. casing pressure on May 19. The same company's LaPrelle No. 4*A* perforated casing at 5080 to 5084 ft. and flowed 155 bbl. of 48° gravity oil daily through ⅛-in. choke under equalized pressures of 450 lb. This sand, at 5073 to 5085 ft., is in the *Heterostegina* zone.

Minnie Bock Field.—The Minnie Bock field was brought in on May 31 by Texas Conservative Oil Company's Minnie Bock No. 1, sec. 55, about 5½ miles southwest of Robston, when it flowed 121 bbl. of 23.6° gravity crude from perforations at 3806 to 3814 ft. in a Catahoula sand from 3805 to 3835 ft.; production was through ⅛-in. choke under pressure of 1240 lb. on tubing and 1600 lb. on casing.

Robston Field.—Shield Oil Company's J. T. Potter No. 1, Herrera grant, 1½ miles northwest of Robston, drilled to 7089 ft., plugged back and flowed 75 bbl. of 42.5° gravity oil from perforations at 5560 to 5566 ft. in Frio sand from 5548 to 5582 ft., on Sept. 6; ⁵⁄₆₄-in. choke was used, and pressures were 950 lb. on tubing and 650 lb. on casing.

New Sands in Existing Fields, Nueces County

Richard King Field.—Southern Minerals Corporation's King No. 16 flowed 38 bbl. of 38° gravity oil through ¼-in. choke under pressures of 550 lb. tubing pressure and 1425 lb. casing pressure, from perforations at 6137½ to 6141 ft. in a Vicksburg sand from 6133 to 6143 ft., a second producing zone for this field. The company's King No. 1*A* flowed 671 bbl. of 39° gravity crude from perforations at 5399 to 5406 ft. from a third sand, in Frio, at 5391 to 5414½ ft. through ¼-in. choke under 1250 lb. tubing pressure and 2075 lb. casing pressure. The same company's King No. 2*B* produced 157 bbl. of 37° gravity crude through ⁵⁄₃₂-in. choke from perforations at 5251 to 5258 ft. in a fourth sand, also in Frio. Pressures were 650 lb. on tubing and 1150 lb. on casing.

Clara Driscoll Field.—A Frio sand from 5290 to 5302 ft. was proved productive by Wellington and Pan-American Oil Company's Driscoll No. 1*B* when it pumped 113 bbl. of 25° gravity crude per day. Total depth was 8194 feet.

South Clara Driscoll Field.—On Dec. 13 Wellington Oil Company's Martin No. 1, a mile east of production, gauged 320 bbl. of 35° gravity oil daily from perforations at 5255 to 5263 ft. in a Frio sand. On April 5, the same company's C. R. Richardson No. 1, in the south part of the field, flowed 151 bbl. of 37° gravity oil from perforations at 6557 to 6566 ft., also in a Frio sand. Choke was ¼ in. and pressures were 200 lb. on tubing and 475 lb. on casing.

Agua Dulce Field.—Two new producing levels were opened in the Agua Dulce field during the year. Union Producing Company's Wallace No. 1 flowed 100 bbl. of distillate with gas daily through ¼-in. choke under 2650 lb. tubing pressure and 2700 lb. casing pressure from perforations at 6615 to 6622 ft. in the Frio.

Process Oil Company's Ingram No. 3 gauged 100 bbl. of distillate and a large volume of gas from perforations at 6932 to 6938 ft. in the Frio.

North Agua Dulce Field.—A second Frio sand from 5575 to 5593 ft. was proved productive in May by Union Producing Company's Harper No. 1, which jetted 106 bbl. of 37.5° gravity oil per day. In December, Union Producing Company's J. J. Eliff No. 2 flowed 100 bbl. of distillate and much gas daily from perforations in a third Frio sand from 5081 to 5088 feet.

Important Extensions to Established Areas, Nueces County

Riverside Field.—Seaboard Oil Company's Wilson No. 2, 4650 ft. west of the cratered discovery well, produced 88 bbl. of 33.5° gravity crude daily from perforations at 4996 to 4999½ ft. in Frio sand logged from 4972 to 4999½ ft.; flow was through ⅛-in. choke under 1175 lb. tubing pressure and 1600 lb. casing pressure. This well established crude-oil production for this field, production heretofore having been gas and distillate.

Union Producing Company's Minnie Brown No. 1, Nueces County

Deepest Test in South Texas.—Although Union Producing Company's Minnie Brown No. 1, deepest test drilled in South Texas, was disappointing as a producer, having been plugged back from 13,728 ft. to an upper sand level of the Agua Dulce field, Nueces County, and completed as a gasser, the well was of great importance geologically and because it penetrated successfully 5000 ft. of troublesome shale that had been an obstacle to deep exploration in this area. The well began operations on Jan. 28, 1938, and reached its total depth of 13,728 ft. on Dec. 30, 1938, after which plug-back operations began. Casing was set to 8007 ft.; below this level the hole was unprotected by pipe. This test, the first to penetrate the Cockfield along the South Texas Gulf Coast, failed to find a single sand body in the Jackson, Cockfield, or that part of the Yegua penetrated, indicating a shaling out of their sand sections toward the coast. Thicknesses of 2347 ft. for the Jackson, 1416 ft. for the Cockfield, and over 1728 ft. for the Yegua in this well compared with an average thickness of 1100 ft. for the Jackson, 300 ft. for the Cockfield and 600 to 700 ft. for the Yegua along the Pettus trend, also indicating a rapid thickening of these formations toward the coast. This well, with an elevation of 105 ft., topped the Heterostegina at 3710 ft., the Frio at 4240 ft., the Vicksburg at 7380 ft., the Jackson at 8237 ft., the Textularia Hockleyensis at 8822 ft., the Cockfield at 10,584 ft., and the Yegua at 12,000 feet.

San Patricio County, South Corpus Christi District

East Mathis Field.—The East Mathis field was brought in by Seaboard Oil Company's A. Persons No. 1, block 29, Paul's subdivision, 6 miles east of Mathis, on June 16, when it was completed for a flow of 54 bbl. of 35.5° gravity crude from perforations at 5260 to 5268 ft. in Frio sand from 5258 to 5270 ft.; pressures were 325 lb. on tubing and 700 lb. on casing. Total depth was 6348 feet. Seaboard Oil Company's Blumberg No. 1, two miles northeast of the discovery well, extended the field and found a second Frio sand from 4417 to 4422 ft. from which it flowed 4,500,000 cu. ft. of gas daily with a spray of 54° gravity distillate through ⅜-in. choke under 1450 lb. tubing pressure and 1600 lb. casing pressure. Total depth was 6015 feet.

Odem Field.—This field was opened on Oct. 27 by Seaboard Oil Company's M. C. Smith No. 1, Hart and Son Survey, 2 miles west of Odem. The well was drilled to 7295 ft., casing was perforated from 6995 to 7000 ft. in Frio sand, and a flow of 45 bbl. of 57° gravity clear distillate with 6,000,000 cu. ft. of gas, was obtained through 3/16-in. choke under 2650 lb. working pressure.

New Sands in Existing Fields, San Patricio County

East White Point.—Plymouth Oil Company's Brooks No. 3 produced 5,000,000 cu. ft. of gas daily through ⅛-in. choke from a Catahoula sand at 4010 to 4015 ft., a second producing zone in this field. Total depth was 8383 ft., probably in the top of the Vicksburg. A Miocene sand at 2495 to 2505 ft. produced gas in Houston Oil Company's Baldwin No. 5*A*, Fulton survey, with total depth 5737 ft., suggesting a third producing zone for East White Point.

White Point Field.—Frio sand production was established in the White Point field by Easterwood and Cage's Dunn No. 1, M. Flores survey, when it flowed 154 bbl. of 29.8° gravity crude from sand at 5672 to 5676 ft. Flow was through ⅛-in. choke under pressures of 500 lb. on tubing and 650 lb. on casing. This is the third producing sand in the field.

East Plymouth Field.—Republic Natural Gas and Byron Rife's A. A. Galler No. 1, one mile southwest of the East Plymouth field, in sec. 26, perforated from 5111 to 5113 ft. in Frio sand logged at 5111 to 5136 ft., and flowed gas through ⅛-in. choke under 1800 lb. tubing pressure and 1850 lb. casing pressure, proving a second producing zone for East Plymouth.

Angelita Field.—A second Frio sand from 6225 to 6235 ft. was proved productive in October by Wellington Oil Company's J. F. Welder Heirs No. 6. The well pumped 32 bbl. of 36° gravity oil daily.

ACKNOWLEDGMENT

The author wishes to extend his appreciation and thanks to James J. Halbouty, student geologist at the University of Texas, for his patient and valuable assistance in assembling and compiling data from many sources and in the final preparation of this report. In several instances, Mr. Halbouty made trips to the field to check doubtful reports, and for these efforts the author is deeply grateful.

Development along Fault Zone of South Central Texas in 1939

By William H. Spice, Jr.,* Member A.I.M.E.

(New York Meeting, February 1940)

No development of major importance has been made in the south central fault-line district of Texas during 1939. Four new fields have been discovered, all of which appear to be of minor importance, with small wells in the Navarro sand, the Taylor marl or the Austin chalk. Drilling along the fault line has not developed any new prospects in the Edwards lime, the most prolific producing horizon of the district. At the close of the year, a few deep tests for lower producing horizons have been projected and should prove to be of interest, and plans are under way for further development of the Pearsall field, which has been under the control of a single company until recently.

Production from the 46 producing fields was maintained at 8,460,000 bbl. for the year, a decrease of approximately 400,000 bbl. under 1938. This decrease is due in part to natural decline of production and in part to decreased allowed production. Approximately 55 producing wells were completed on proven acreage in the Darst Creek and Salt Flat fields.

No new lease plays were made during the year, although approximately the same amount of land, 600,000 acres, remained under lease during the year.

Some geophysical operations of various types were carried on along the fault-line area itself and also in the Edwards Plateau and in the area south and southeast of the main fault line.

Summarized at meeting; manuscript received at the office of the Institute May 8, 1940.

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TABLE 1.—*Oil and Gas Production in South Central Texas Fault Zone*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Alta Vista, *Bexar*	1912	300	0	114,767	5,725
2	Branyon, *Caldwell*	1930	900	0	2,138,546	570,751
3	Burdette Wells, *Caldwell*	1936	200	0	53,467	12,689
4	Buchanan, *Caldwell*	1928	250	0	369,138	46,296
5	Byersville, *Williamson*	1933	360	0	497,646	30,997
6	Carroll, *Bastrop*	1932	100	0	96,621	6,336
7	Cedar Creek, *Bastrop*	1932	100	0	258,719	22,105
8	Chapman, *Williamson*	1928	450	0	4,220,465	68,250
9	Chicon Lake, *Medina*	1920	280	*y*	47,706	9,664
10	Chriesman, *Burleson*	1938	10	0	15,725	4,725
11	Dale, *Caldwell*	1927	250	0	1,366,252	91,466
12	Dale, West, *Caldwell*	1937	240	0		
13	Dale, North, *Bastrop*	1932	320	0		33,356
14	Darst Creek, *Guadalupe*	1928	1,860	0	46,573,407	2,630,830
15	Darst Creek Extension, *Guadalupe*	1935	200	0	334,409	41,216
16	Dunlap, *Caldwell*	1930	120	0	323,110	19,422
17	Dunlay, *Medina*	1938	30	0	1,988	55
18	Eckert, *Bexar*	1927	850	0	847,359	40,121
19	Gas Ridge, *Bexar*	1912	80	150	67,945	2,653
20	Hilbig, *Bastrop*	1932	260	0	1,479,367	99,149
21	Ina, *Medina*	1922	340	0	115,359	2,941
22	Kimbro, *Travis*	1935	40	0	3,275	1,630
23	La Coste, *Bexar*	1939	40	10	1,985	774
24	Larremore, *Caldwell*	1927	80	0	307,098	15,387
25	Lone Oak, *Bexar*	1934	10	0	4,449	716
26	Lytton Springs, *Caldwell*	1925	1,360	0	8,384,104	102,461
27	Luling, *Caldwell-Guadalupe*	1921	2,200	0	72,554,541	2,402,812
28	Manda, *Travis*	1935	40	0	22,471	933
29	Manford, *Guadalupe*	1929	40	0	395,768	7,292
30	Minerva-Rockdale, *Milam*	1921	4,250	0	3,524,850	69,450
31	Nash Creek, *Guadalupe*	1936	10	0	46,183	3,751
32	Pearsall, *Frio*	1933	650	0	989,111	173,183
33	Red Rock, *Bastrop*	1939	35	0	2,169	2,169
34	Riddle, *Bastrop*	1938	50	0	44,291	30,633
35	Salt Flat, *Caldwell*	1928	1,250	0	39,709,907	1,598,815
36	Somerset, *Atascosa-Bexar*	1912	11,390	0	10,536,950	200,176
37	Spiller, *Guadalupe*	1938	30	0	8,275	4,800
38	Southton-Yturri, *Bexar*	1921	650	0	635,447	13,256
39	Taylor, *Medina*	1924	30	0	34,411	1,369
40	Thrall, *Williamson*	1914	475	0	2,432,328	12,848
41	Walnut Creek, *Caldwell*	1938	50	0	6,487	876
42	Von Ormy, *Bexar*	1933	650	0	200,771	43,809
43	Yost, *Bastrop*	1928	120	0	898,741	14,348
44	Zoboroski, *Guadalupe*	1935	180	10	189,038	24,469
	GAS ONLY					
45	Adams, *Medina*	1926	0	2,000	0	0
46	Chittim, *Maverick*	1929		100[1]	41,334	11,334

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[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Gas and distillate.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]
				During 1939		End of 1939			Number of Wells				
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[e]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	
1	0	0	35	0	2	0	33	0	0	33	*y*	0	0
2	0	0	184		25	1	158	0	0	158	*y*	*y*	0
3	0	0	12		7	2	2	1	0	2	200	0	0
4	0	0	40	4	4	3	33	0	0	33	*y*	*y*	0
5	0	0	43		3	5	35	0	0	35	0	0	RP
6	0	0	8	0	1	0	7	0	0	7	0	0	0
7	0	0	10	0	1	0	9	0	0	9	100	0	0
8	0	0	70	0	0	1	69	0	0	69	400	0	0
9	*y*	*y*	50	13	0	0	50	0	0	50	*y*	0	0
10	0	0	1	0	0	0	1	0	0	1	*y*	*y*	0
11	0	0	54	0	0	2	52	0	0	52	150	0	0
12	0	0											
13	0	0	10	0	1	0	9	0	0	9	100	0	0
14	0	0	345	17	7	2	336	0	3	333	350	0	0
15	0	0	11	0	2	0	9	0	0	9	200	0	0
16	0	0	14	0	3	0	11	0	0	11	400	0	0
17	0	0	1	0	0	0	1	0	0	1	*y*	0	0
18	0	0	120	0	2	0	118	0	0	118	*y*	0	0
19	*y*	*y*	79	0	1	0	15	63	0	15	*y*	0	0
20	0	0	12	0	0	0	12	0	12	0	1,240	*y*	PM
21	0	0	9	1	2	2	5	0	0	5	*y*	0	0
22	0	0	4	1	0	0	4	0	0	4	*y*	0	0
23	0	0	4	2	2	0	1	1	0	1	*y*	0	0
24	0	0	12	0	0	2	10	0	0	10	*y*	0	0
25	0	0	1	0	0	0	1	0	0	1	*y*	0	0
26	0	0	157	0	1	4	152	0	0	152	1,250	0	0
27	0	0	600	*y*	5	10	582	3	0	582	1,500	*y*	0
28	0	0	2	0	0	1	1	0	0	1	*y*	0	0
29	0	0	1	0	0	0	1	0	0	1	1,250	*y*	0
30	0	0	402	0	12	0	390	0	0	390	*y*	0	0
31	0	0	1	0	0	0	1	0	0	1	340	0	0
32	0	0	20	0	0	2	18	0	7	11	1,500	*y*	0
33	0	0	2	2	0		2	0	0	2	*y*	0	0
34	0	0	5	1	0	3	2	0	0	2	*y*	0	0
35	0	0	287	12	7	9	271	0	3	268	200	*y*	0
36	0	0	914	0	1	0	913	0	0	913	300	0	0
37	0	0	6	0	3	0	3	0	0	3	*y*	0	0
38	0	0	103	0	1	0	102	0	0	102	*y*	0	0
39	0	0	6	0	3	0	3	0	0	3	*y*	0	0
40	0	0	16	0	2	0	14	0	0	14	400	0	0
41	0	0	3	0	0	1	2	0	0	2	*y*	0	0
42	0	0	108	6	0	1	107	0	0	107	*y*	0	0
43	0	0	6	0	0	1	5	0	0	5	400	0	0
44	*y*	*y*	21	4	6	3	11	1	0	11	150	*y*	0
45	*y*	*y*	58	0	0	0	0	46	0	0	*y*	*y*	0
46	*y*	*y*	19	0	0	0	1	5	1	0	*y*	*y*	0

TABLE 1.—(*Continued*)

Line Number	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
1	35	0.3	Navarro sands	CreU	S	15–20	220	250	20	F	Trinity sand	4,535
2	37	0.8	Austin chalk, Edwards lime	CreU	L		1,816	2,275	*y*	F	Edwards lime	2,450
3	32	0.8	Edwards lime	CreL	L	Crev.	2,210	2,235	15	F	Edwards lime	2,420
4	36	0.2	Serpentine	CreU	P	12	1,750	2,075	*y*	Intn	Edwards lime	2,483
5	37	0.2	Serpentine	CreU	P	20	850	900	*y*	Intn	Edwards lime	2,000
6	36	0	Serpentine	CreU	P	12	2,300	2,378	78	Intn	Edwards lime	2,919
7	35	0.2	Serpentine	CreU	P	15–20	1,650	1,700	50	Intn	Edwards lime	2,300
8	36	0.2	Serpentine	CreU	P	20	1,750	1,915	20	Intn	Edwards lime	3,226
9	21	0.1	Navarro sands	CreU	S	15	260	750	20	D	Edwards lime	1,725
10	34.5	*y*	Edwards lime	CreL	L	*y*	6,167	6,182	*y*	F	Edwards lime	6,340
11	37	0.2	Dale lime, serpentine	CreU	LP	15	1,915	2,250	30	Intn	Edwards lime	2,661
12												
13	37	0.2	Dale lime, serpentine	CreU	LP	15						
14	36	0.8	Edwards lime	CreL	L	30	2,650	2,700	30	F	Travis Peak	5,509
15	33.6	0.5	Austin chalk	CreU	C	5–25	2,375	2,450	100	F	Edwards lime	3,200
16	36	0.6	Austin chalk	CreU	C	Crev.	2,375	2,300	15	F	Edwards lime	2,420
17	21	*y*	Serpentine	CreU	P	*y*	542	714	*y*	Intn	Austin chalk	851
18	34	0.3	Navarro sands	CreU	S	16	620	790	10	F	Edwards lime	1,590
19	22	0.4	Navarro sands	CreU	S	15–20	230	760	15	A	Travis Peak	3,460
20	37	0.2	Serpentine	CreU	P	12	2,450	2,575	50	Intn	Edwards lime	3,250
21	19	0.7	Navarro sands	CreU	SH	15	940	960	10	T	Edwards lime	2,048
22	36.5	*y*	Serpentine	CreU	P	*y*	660	670	*y*	Intn	Edwards lime	1,280
23	31	*y*	Anacacho lime	CreU	L	*y*	1,150	1,190	*y*	N	Austin chalk	1,227
24	23	0.6	Edwards lime	CreL	L	30	1,285	1,315	35	F	Glen Rose	2,150
25	33.4	*y*	Navarro-Taylor	CreU	S	*y*	1,480	1,620	18	F	Edwards lime	2,250
26	31.5	0.4	Serpentine	CreU	P	12	1,535	1,820	*x*	Intn	Edwards lime	2,050
27	27	0.9	Edwards lime	CreL	L	25	2,100	2,200	50	F	Schist	7,859
28	34	0.4	Serpentine	CreU	P	15–25	720	757	*x*	Intn	Taylor marl	850
29	37	0.9	Austin chalk	CreU	C	35	2,260	2,310	30	F	Edwards lime	2,800
30	38	0.2	Navarro sands	CreU	SH	16	600	1,700	15	T	Edwards lime	5,000
31	27	0.8	Taylor marl	CreU	L	*y*	2,570	2,585	30	F	Edwards lime	3,342
32	28	0.4	Navarro sands Austin chalk Buda lime	CreU CreL	S C L	20 *y*	3,920	5,850	15 *x*	N	Travis Peak	10,050
33	37	*y*	Dale lime	CreU	L	*y*	*y*	2,300	*y*	F	Edwards lime	2,550
34	39	*y*	Austin chalk, serpentine	CreU	CP	*y*	1,667	1,747	*y*	F	Austin chalk	1,777
35	36	0.6	Edwards lime	CreL	L	30	2,670	2,740	25	F	Edwards lime	2,918
36	36	1.4	Navarro sands	CreU	SH	22	1,200	2,100	30	TF	Travis Peak	5,311
37	38.3	*y*	Buda lime	CreL	L	*y*	2,012	2,298	*y*	F	Edwards lime	2,382
38	32	0.5	Navarro sands	CreU	S	16	600	800	10	F	Glen Rose	3,850
39	18	0.4	Navarro sands	CreU	SH	15	290	400	15	F	Edwards lime	1,285
40	37	0.3	Serpentine	CreU	P	25	700	1,000	75	Intn	Travis Peak	3,290
41	36	*y*	Serpentine	CreU	P	*y*	1,230	1,336	100	Intn	Austin chalk	1,900
42	34	0.4	Navarro sands	CreU	SH	10	506	730	20	F	Edwards lime	2,835
43	27	0.3	Serpentine	CreU	P	15–25	1,335	1,500	100	Intn	Edwards lime	2,600
44	30.4	0.8	Austin chalk	CreU	C	10	2,050	2,200	75	F	Edwards lime	2,600
45	0	0	Navarro-Taylor sands	CreU	SH	*y*	900	*y*	*y*	F	Edwards lime	2,289
46	42–44	*y*	Buda, Edwards, Glen Rose	CreL	L	*y*	3,205 3,255 5,650	*y* *y* *y*	*y*	AN	Travis Peak	7,635

West Texas Oil Development in 1939

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(New York Meeting, February 1940)

Although oil production in West Texas in 1939 reached the highest figure for any year since the inauguration of proration, drilling activity continued in the decline that had commenced the previous year. Production totaled 79,469,341§ bbl. of oil during 1939 as compared with 71,257,541§ bbl. in 1938 and 75,743,000 in 1937. The number of wells completed in 1939 was 1850, compared with 2045 in 1938 and 2806 in 1937. Several factors combined to cause the decrease in drilling activity, principally the continued increase in the length of time required to obtain a return of investment and the scarcity of important new discoveries during the past two years.

Of the 1850 completions 1638 resulted in oil wells, 4 were gas wells, 168 were dry holes and 40 were abandoned locations; 1990 new locations were made during the year. The ratio of dry holes to producing wells completed was one dry hole to each 9.75 oil wells, compared with one dry hole to each 7.48 oil wells completed during 1938. This large decrease in dry holes was due to a marked decline in the number of wildcat wells drilled, there having been only 120 wildcat completions during 1939.

In addition to the lessened exploration work, the decline in activity was largely accounted for by the slowing up of operations in the older pools of Ector, Howard and Winkler Counties. Ector County, which had led West Texas in 1938 with 622 new oil wells, furnished only 485 producers in 1939, but was still the leader for the West Texas district. The largest gain in activity was in Yoakum County, where 350 oil wells were completed in the Denver-Wasson field against 152 during 1938.

Most of the older oil fields have been almost completely drilled up, only a few new producers still being completed from time to time in

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§ *Oil and Gas Journal.*

TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	*County,* Field	Year of Discovery	Area Proved, Acres		Total Oil Production Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	*Andrews:* Deep Rock (Walker-Fuhrman)	1931	4,370	0	2,630,494	606,091
2	Emma	1937	960	0	324,981	279,031
3	Means	1934	8,000	0	3,202,625	933,860
4	Parker	1934	160	0	59,108	9,656
5	Nix	1938	40[1]	0	*y*	*y*
6	Shafter Lake	1938	40[1]	0	*y*	*y*
7	*Cochran:* Dean	1937	360	160	43,417	24,614
8	Duggan	1936	5,000	0	322,283	160,486
9	*Crane-Upton:* Church Fields, Gulf McElroy, McClintic	1926	13,500	0	112,259,890	3,696,244
10	*Crane:* Dune	1938	2,200	0	153,793	151,405
11	Sand Hills (Permian)	1930	4,000	0	1,552,429	437,432
12	Sand Hills (Ordovician)	1936	500	0	249,013	78,890
13	*Crockett:* Crockett	1938	1,360	0	96,034	87,403
14	World-Powell	1926	2,030	0	6,615,542	347,057
15	*Dawson:* Allbaugh	1936	40[1]	*y*	1,000[1]	0
16	Wilson	1937	40[1]	*y*	2,500[1]	0
17	*Ector:* Addis (South Cowden)	1933	1,000	0	959,434	839,542
18	North Cowden	1930	13,360	0	12,462,746	3,172,426
19	North Cowden (deep)	1939	120	0	12,416	12,416
20	Foster	1936	11,000	0	5,673,598	2,908,756
21	Goldsmith	1934	26,040	*y*	16,582,027	7,376,238
22	Harper	1933	4,500	0	5,061,724	1,946,630
23	Landreth-Johnson	1935	1,280	0	76,399	24,588
24	*Ector-Crane:* Penn-Jordan-Waddell	1927	16,500	0	24,067,664	2,796,124
25	*Gaines:* Cedar Lake	1939	160	0	5,919	5,919
26	Landreth-Kirk	1936	40[1]	0	1,500[1]	0
27	Seminole	1937	5,000	0	330,936	177,439
28	*Gaines-Yoakum:* Wasson Denver	1936	55,000	0	9,053,620	5,929,335
29	*Garza:* Garza (Emerald)	1925	320	0	94,158	4,540
30	*Glasscock:* Dodson-Duffy	1936	40[1]	0	13,000[1]	3,639[1]
31	*Glasscock-Howard:* Chalk-Roberts	1926	21,700	0	90,307,062	5,209,467
32	1400-foot pay	1927	1,700	0	[2]	[2]
33	1700-foot pay	1926	4,000	0	[2]	[2]
34	2200-foot pay	1929	8,000	0	[2]	[2]
35	2500-foot pay	1928	2,000	0	[2]	[2]
36	3000-foot pay	1928	6,000	0	[2]	[2]
37	*Hockley:* Slaughter	1937	20,000	0	630,363	474,478
38	*Howard:* Iatan-Denman	1925	6,500	0	11,841,908	1,860,577
39	Moore Bros. (Snyder)	1937	1,000	*y*	1,195,539	762,010
40	*Irion:* Irion	1929	340	0	144,033	5,707
41	*Loving:* Mason	1936	350	0	300,485	90,596
42	Wheat	1925	4,500	0	7,782,310	403,009
43	*Mitchell:* Westbrook	1921	4,000	0	10,530,579	231,805
44	*Pecos:* Apco	1939	120	0	22,884	22,884
45	Fromme	1939	320	80	9,093	9,093
46	Masterson	1927	1,000[1]	0	795,604	90,622
47	McKenzie	1934	160[1]	*y*	2,447	0
48	Netterville	1934	1,600	0	297,898	53,387
49	Pecos Valley	1928	3,400	0	1,549,093	485,637
50	Richards (Prior)	1929	160	0	28,724	1,195
51	Shearer	1938	320	0	535,733	463,570
52	Tobarg	1928	1,300	0	5,846,922	608,361
53	Taylor Link (sand)	1929	450	0	533,881[1]	19,590
54	Taylor Link (lime)	1929	1,620	0	5,199,033[1]	519,468
55	White and Baker	1935	320	640	42,162	34,437
56	Yates (sand)	1933	700	0	384,374	37,280
57	Yates (lime)	1926	20,000	0	247,403,819	7,737,871
58	*Pecos-Ward:* Payton	1937	1,770	0	1,377,719	1,092,641
59	*Regan:* Big Lake (2400-ft.)	1923	275	0	[3]	[3]

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[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Estimated.

[2] Production of various "pays" included in field total.

[3] Production included under Big Lake Ordovician.

TABLE 1.—(*Continued*)

	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		
				During 1939		End of 1939			Number of Wells				
Line Number	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Repressuring Operation[d]
1	*x*	*y*	63	11	0	0	63	0	48	15	1,800	*y*	
2	*x*	*y*	27	18	0	0	27	0	15	12	*y*	*y*	
3	4,133.3	1,470.6	101	27	0	0	98	3	65	35	1,900	1,596	
4	0	0	0	0	0	0	2	0	0	2	*x*	*x*	
5	0	0	1	0	0	1	0	0	0	0	*y*	*y*	
6	0	0	1	0	0	1	0	0	0	0	*y*	*y*	
7	40	22.6	3	1	0	1	2	1	1	1	*x*	*x*	
8	187.6	93.4	15	7	0	0	14	0	11	4	1,600[1]	1,440	
9	*y*	*y*	516	42	1	0	490	0	175	315	750	*y*	
10	*x*	*x*	21	18	5	0	16	0	6	10	740	*y*	
11	1,351.9	392.1	61	15	1	0	61	0	59	2	2,100	1,757	
12	453	178	7	1	0	0	7	0	5	2	2,760	2,758[1]	
13	*x*	*x*	27	18	0	0	27	0	3	24	*x*	*x*	
14	*x*	*x*	64	6	2	0	46	0	0	46	*x*	*x*	
15	0	0	2	0	0	2	0	0	0	0	*y*	*y*	
16	0	0	1	0	1	0	0	0	0	0	*y*	*y*	
17	*x*	*y*	19	2	0	0	15	0	7	8	*x*	*x*	
18	44,365	10,153	314	85	4	0	310	0	286	24	1,740	1,384	
19	12[1]	12[1]	3	3	0	0	3	0	2	1	1,300[1]	1,290	
20	3,595[1]	1,885[1]	391	186	0	0	391	0	235	156	1,521	1,232	
21	40,353	12,649	761	255	0	3	754	4	716	38	1,675	1,411	
22	*y*	1,551,562	183	0	0	0	183	0	89	94	*x*	*y*	
23	*x*	*x*	6	4	0	0	6	0	3	3	*x*	*y*	
24	*y*	*y*	360	51	0	0	358	2	259	99	1,525	*y*	
25	1.391	1.391	3	3	0	0	3	0	3	0	1,876	1,825[1]	
26	0	0	1	0	1	0	0	0	0	0	*y*	*y*	
27	675[1]	350[1]	22	13	0	0	22	0	19	3	2,050	2,000[1]	
28	10,683	6,997	612	460	0	0	612	0	596	16	1,800[1]	1,645	
29	*x*	*x*	8	0	*y*	*y*	5	0	0	5	*x*	*x*	
30	0	0	1	0	0	1	0	0	0	2	*y*	*y*	
31	*x*	*x*	*x*	17	4	7	842	0	0	842	*x*	*x*	
32	*x*	*x*	103	2	0	0	103	0	0	103	*x*	*x*	
33	*x*	*x*	268	1	3	6	211	0	0	211	*x*	*x*	
34	*x*	*x*	*x*	0	0	1	49	0	0	49	*x*	*x*	
35	*x*	*x*	283	0	0	0	283	0	0	283	*x*	*x*	
36	*x*	*x*	*x*	14	1	0	196	0	0	196	*x*	*x*	
37	477	359	48	33	0	0	47	0	44	3	1,725[1]	1,502	
38	*x*	*x*	265	15	1	0	264	0	4	260	*x*	*x*	
39	*x*	*x*	90	26	*y*	0	90	*y*	1	89	*x*	*x*	
40	*x*	*y*	17	0	0	0	9	0	0	9	*x*	*x*	
41	0	0	10	2	0	2	8	0	6	2	*y*	*y*	
42	*x*	*y*	85	1	1	1	83	0	56	27	1,650	*y*	
43	*x*	*x*	136	0	0	0	95	0	0	95	1,000[1]	*x*	
44	*x*	*x*	3	3	0	0	3	0	3	0	*x*	*x*	
45	*x*	*x*	6	6	0	0	5	1	4	1	*x*	*x*	
46	*x*	*x*	40	13	*y*	*y*	22	0	0	22	*y*	*y*	
47	*x*	*x*	1	0	1	0	0	0	0	0	*y*	*y*	
48	0	0	23	3	2	0	21	0	15	6	*y*	*y*	
49	0	0	166	41	8	*y*	158	0	100	58	*y*	*y*	
50	*x*	*x*	3	0	0	0	2	0	0	2	*x*	*x*	
51	*x*	*y*	38	12	0	0	38	0	35	3	*x*	*y*	
52	*x*	*x*	215	12	0	0	215	0	0	215	*x*	*x*	
53	*x*	*x*	23	0	0	0	8	0	0	8	*x*	*x*	
54	*x*	*x*	83	18	0	2	81	0	0	81	*x*	*x*	
55	*x*	*y*	8	4	0	0	7	1	7	0	900[1]	*y*	
56	*x*	*x*	10	0	0	0	10	0	0	10	100	*x*	
57	116,559	1,479	556	4	0	0	552	0	527	29	700	532	
58	*y*	*y*	135	78	0	0	135	0	127	8	750[1]	*y*	
59	*x*	*x*	21	0	0	1	4	0	0	4	*x*	*x*	

TABLE 1.—(*Continued*)

Line Number	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
	Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	28	y	Big Lime	Per	D	Por	4,350	4,625	25	A	Permian Ls	5,088
2	34.6	y	Big Lime	Per	D	Por	4,190	4,225	25	A	Permian Ls	4,350
3	29	y	Big Lime	Per	D	Cav	4,475	4,535	35	A	Permian Ls	5,088
4	29.5	y	Big Lime	Per	D	Por	4,627	4,790	5	MC	Permian Ls	4,814
5	27	y	Big Lime	Per	D	Por	y	4,526	y	A	Permian Ls	4,526
6	y	y	Yates sand	Per	S	Por	y	2,952	y	y	Permian Ls	2,952
7	30	y	Big Lime	Per	DL	Por	4,900	5,010	y	y	Permian Ls	5,076
8	31	y	Big Lime	Per	DL	Por	5,000	5,050	y	MC	Permian Ls	5,098
9	32	y	Big Lime	Per	DL	15	2,800	3,000	75	A	Ordovician	12,786
10	36	y	Big Lime	Per	DL	Por	3,150	3,270	40	A	Permian Ls	3,503
11	35	y	Big Lime	Per	D	Por	4,299	4,421	25	AD	Ordovician	6,450
12	44.7	0	"Simpson" Ellenberger	Ord	Ds	Cav	5,950	6,100	18	AF	Pre-Cambrian	7,158
13	30	y	Big Lime	Per	DL	Por	1,450	1,495	10[1]	A	Permian	1,893
14	29	x	Big Lime	Per	DL	Por	2,450	2,550	13	A	Permian	3,695
15	31	y	Big Lime	Per	DL	Por	4,970	5,038	y	A	Permian	5,055
16	37	y	Delaware sand	Per	S	Por	y	5,100	y	A	Permian	5,100
17	32	y	Big Lime	Per	Ds	Por	4,000	4,350	y	A	Permian	4,627
18	34	y	Big Lime	Per	DS	Por	4,000	4,350	40 ±	A	Permian	5,200
19	34	1.0	Holt Lime	Per	DL	Por	5,100	5,150	x	A	Permian	5,200
20	36	y	Big Lime	Per	DL	Por	4,100	4,310	35 ±	A	Permian	4,517
21	36	1.9	San Andres, Up.	Per	DL	Por	4,164	4,233	69	A	Permian	4,518
22	36	y	Big Lime	Per	DL	Por	4,000	4,200	20	MC	Permian	4,518
23	36	y	Big Lime	Per	DS	Por	4,100	4,166	30	A	Permian	6,098
24	36	y	Judkins pay	Per	D	Por	3,450	3,600	40	A	Permian	4,002
25	33	2.1	Big Lime	Per	LS	Por	4,650	4,760	70 ±	A	Permian	4,830
26	27	y	Big Lime	Per	DS	Por	4,796	4,850	50	A	Permian	4,870
27	37.5	y	Big Lime	Per	DL	Por	5,050	5,300	y	A	Permian	5,358
28	34	1.8	Big Lime	Per	DL	Por	4,900	5,100	y	A	Permian	5,346
29	39	y	Big Lime	Per	SL	Por	2,000	2,510	10	A	Permian	4,801
30	y	y	Big Lime	Per	DL	Por	2,632	2,664	4	D	Permian	3,247
31	y	y	Data: Producing formation and deepest zone tested included separately									
32	33	1.0	Yates sand	Per	S	Por	1,280	1,400	20	A	Ordovician	10,906
33	32.0	0.8	"1800-ft. pay"	Per	S	22	1,650	1,750	20	A	Ordovician	10,906
34	30.0	1.6	"2200-ft. pay"	Per	DL	Por	2,150	2,300	30	A	Ordovician	10,906
35	y	y	"2500-ft. pay"	Per	DL	Por	2,400	2,500	30	A	Ordovician	10,906
36	27.0	3.4	"3000-ft. pay"	Per	DL	Por	2,900	3,000	20	A	Ordovician	10,906
37	32	1.9	Big Lime	Per	DL	Por	4,950	5,030	y	MC	Permian	5,521
38	27	y	Big Lime	Per	DL	Por	2,450	2,800	50	A	Permian	4,220
39	30	y	Big Lime	Per	D	Por	2,651	2,825	174	A	Permian	3,205
40	38	0	Yates sand	Per	S	Por	1,400	1,410	10	M	Permian	3,972
41	39	y	Delaware sand	Per	S	Por	3,931	3,953	10	T	Permian	4,165
42	38	y	Delaware sand	Per	S	Por	4,290	4,310	7	MC	Permian	5,083
43	24	y	Big Lime	Per	DL	Por	2,800	3,000	50	MC	Permian	5,250
44	41.6	x	Ellenberger	Ord	LS	Por	4,548	4,581	33	Af	Ordovician	4,614
45	27	y	Shipley sand	Per	S-DL	Por	1,400 1,640	1,450 S 1,670 L	20 20	D	Permian	1,676
46	28	y	Pecos Valley sand	Per	S	Por	1,200	1,400	5	M	Permian	1,675
47	y	y	Yates sand	Per	S	Por	1,338	1,378	10	T	Permian	2,800
48	y	y	Yates sand	Per	S	Por	2,200	2,300	15	A	Permian	2,459
49	31	y	Yates sand	Per	S	Por	1,300	1,600	15	A	Permian	2,550
50	24	y	Yates sand	Per	SH	Por	1,385	1,400	25	A	Permian	4,375
51	35	y	Pecos Valley sand	Per	S	Por	1,415	1,465	y	y	Ordovician	4,595
52	19	y	Tobarg sand	Cre	S	Por	400	445	20	AL	Permian	1,400
53	28	y	Yates sand	Per	S	Por	1,016	970	30	A	Permian	2,185
54	30	y	Big Lime	Per	DL	Por	1,630	1,675	15	A	Permian	2,185
55	y	y	Big Lime	Per	DS	Por	1,650	1,700	10	A	Ordovician	9,811
56	32	0	Yates sand	Per	S	Por	900	1,100	15	AL	Permian	1,852
57	30	y	Big Lime	Per	DL	Cav	1,310	1,450	100	A	Permian	1,938
58	37	0	Yates sand	Per	S	Por	2,000	2,080	80	A	Shipley Ls	3,200
59	35	y	Big Lime	Per	S	Por	2,375	2,500	40	A	Lower Ord	9,562

them. The most active area at the close of the year was the Denver-Wasson field of Yoakum and Gaines Counties, which had already spread over an area approximately 50,000 acres, and which still had many undrilled locations. The Seminole field, Gaines County, which was discovered several years ago but which had remained quiescent owing to lack of pipe-line outlet, saw a revival of drilling activity upon the promise of the building of two pipe lines. This important pool will probably see continuous orderly development during the ensuing year. The large areas that have been proven in Hockley and Cochran Counties continued to be developed very slowly without any prospect of improvement in the near future. In Pecos County the shallow sand district of the Payton-Pecos Valley-Masterson trend continued to receive a considerable amount of attention and completed many small wells, although profits were at a precarious level. The Goldsmith, North Cowden and Foster pools in Ector County were extended to an important degree during the year and still have many proven undrilled locations.

TABLE 1.—(*Continued*)

Line Number	*County*, Field	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
60	*Regan:* Big Lake (3000-ft.)	1923	3,000	0	[3]	
61	Big Lake Ordovician	1928	1,300	0	94,109,239	2,345,949
62	Grayson	1928	640	0	602,009	38,692
63	*Reeves:* Anthony	1939	*y*	*y*	1,437	1,437
64	Toyah	1919	640	0	6,500	0
65	*Schleicher:* Opp	1939	*y*	*y*	1,865	1,865
66	Page	1939	*y*	*y*	10,361	10,361
67	*Scurry:* Ira-Northwest	1924	1,800[1]	*y*	198,648	72,098
68	*Upton-Crane:* McCamey-Hurdle-Herrington-Crane Cowden	1925	20,000	0	49,659,680	5,105,475
69	*Upton:* Webb-Ray (Cordova Union)	1936	160	0	41,455	10,014
70	*Ward:* Dobbs	1937	40	0	15,313	2,200
71	Estes	1936	3,450	0	8,119,803	2,307,454
72	Magnolia Sealey	1938	380	0	219,706	125,651
73	Monroe	1930	80[1]	0	41,815	7,269
74	North Ward[4]	1929	*y*	*y*	19,522,518	2,233,169
75	South Ward	1930	11,800	0	24,533,243	2,292,231
76	Shipley	1929	2,500	*y*	*y*	440,435
77	*Winkler:* Eaves	1936	320	0	259,871	100,650
78	Emperor	1936	1,880	320	1,769,186	486,304
79	Halley	1935	820	10	641,117[1]	135,615
80	Hendrick	1923	11,040	160	199,578,191	3,326,736
81	Henderson	1935	2,800[1]	*y*	3,448,630	877,496
82	Kermit	1928	18,260	0	23,288,084	4,787,212
83	Keystone (Colby sand)	1935	6,400	0	821,036	742,758
84	Keystone (lime)	1935	9,500	0	3,164,112	621,773
85	Leck	1927	960[1]	*y*	3,556,222	106,580
86	Scarbrough	1927	1,920	0	4,397,256	577,435
87	Sealey[4]	1932	[4]	[4]	[4]	[4]
88	*Yoakum:* Bennett	1936	2,500±	*y*	2,155,366	1,208,172
89	Bohago-Bond	1938	40	0	15,031	8,392
90	Waples Platter	1939	*y*	*y*	9,244	9,244

[4] Sealey production included under N. Ward Oct. 1, 1939.

Additional drilling in most other pools will depend largely upon the future trend of prices and allowables.

DISCOVERIES

For the second successive year discoveries of new oil fields were remarkably few. However, two of the 1939 discoveries may prove to be of real importance, whereas none of the new fields of 1938 have shown themselves to be of first-class magnitude.

Apco Field.—The Apco field is the first to produce from the Ordovician in Pecos County and the third Ordovician field in West Texas. Situated in the old Masterson shallow pool on a pronounced local structure on the north flank of the great "Ft. Stockton High," it occupies a strategic position and may be the forerunner of important developments. The first well was completed in May 1939 by Anderson and Prichard as their No. 1 Masterson, in sec. 104, bl. 10, H. and G. N. survey. Total depth was 4595 ft. and initial production 197 bbl. of high-gravity sweet oil. Producing horizon was the Ellenberger limestone. Subsequently

TABLE 1.—(*Continued*)

	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		
				During 1939		End of 1939			Number of Wells				
Line Number	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Repressuring Operation^d
60	x	x	261	0	6	1	186	0	0	186	x	x	
61	x	y	24	1	0	2	12	3	5	7	3,600	y	
62	x	x	5	0	0	0	5	0	0	5	x	y	
63	x	x	1	1	0	0	1	0	1	0	x	x	
64	0	0	35	0	y	35y	y	0	0	0	y	y	
65	x	x	1	1	0	0	1	0	1	0	x	x	
66	y	y	4	2	0	2	1	1	1	0	x	y	
67	y	y	33	22	0	0	33	0	4	29	y	y	
68	x	x	1,035	50	47	7	996	0	1	995	x	x	
69	x	x	5	0	0	0	4	0	0	4	x	x	
70	x	x	2	0	0	0	1	0	0	1	x	x	
71	x	y	320	20	3	0	317	0	286	31	1,370	820	
72	x	y	38	11	0	0	38	0	29	9	x	y	
73	y	y	2	1	0	0	0	0	2	0	y	y	
74	x	x	369	34	y	1	368	0	359	14	x	y	
75	x	x	y	20	37	13	653	1	360	307	1,370	x	
76	x	x	104	6	1	0	102	1	11	91	x	y	
77	y	y	7	0	0	0	7	0	4	3	y	y	
78	x	x	92	17	0	3	82	5	84	3	1,300	1,100	
79	x	x	26	0	0	2	24	2	16	8	1,235	y	
80	y	y	631	0	41	0	326	0	90	236	1,720^1	x	
81	y	y	137	10	0	0	137	y	134	3	1,450	y	
82	47,756	16,031	887	7	0	10	861	16	661	200	1,450	632	PM
83	y	y	137	75	0	0	137	0	120	9	y	y	
84	x	y	76	10	0	0	76	0	74	2	y	y	
85	y	y	17	1	0	y	9	y	1	8	y	y	
86	x	y	134	10	0	0	124	0	85	49	1,200	y	
87	^{4}	^{4}	^{4}	^{4}	^{4}	^{4}	^{4}	^{4}	^{4}	^{4}	y	y	
88	y	y	117	62	0	0	117	y	111	6	x	x	
89	x	x	1	0	0	0	1	0	0	1	x	x	
90	y	y	1	1	0	0	1	0	0	1	x	x	

two offsets drilled into igneous rocks without encountering any Ordovician. Three additional good producers have been completed, but the extent of the field cannot be determined from present information.

Cedar Lake Field.—The discovery well in Cedar Lake field was the direct result of a seismograph survey, although some earlier drilling had furnished information that pointed to the presence of a large subsurface feature. Stanolind Oil and Gas Company's No. 1 Raynor, sec. 3, bl. C-30, P.S.L., near the northeast corner of Gaines County, was the first producer. It was completed in September 1939 for an initial production of 1278 bbl. at a depth of 4770 ft., plugged back from 4830. Although 115 ft. of saturated section was shot with 625 quarts, an insufficient gas volume was developed to flow the well, and gas from the shallower Yates sand is used for gas lift. Three subsequent wells have been of approximately the same caliber and have given no indication as to the limits of the field.

Lehn Field.—This new shallow pool, between the Masterson and Pecos Valley pools in Pecos County, was opened by Leidecker and Cain's

TABLE 1.—(*Continued*)

	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
							Depth, Avg. Ft.					
Line Number	Gravity A.p.i. at 60°F. Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
60	36	y	Big Lake Ls	Per	D	Por	2,960	3,000	60	AD	Lower Ord	9,562
61	44	y	Ellenberger Ls	Ord	DL	Por	8,200	8,900	x	D	Lower Ord	9,562
62	32	y	Big Lime	Per	DL	DL	3,050	3,100	y	D	Mississippian	9,967
63	30	y	y	y	y	y	y	1,680	y	y	y	y
64	27	y	Big Lime	Per	DL	Por	100	y	y	MC	Pennsylvanian	5,250
65	34	y	y	y	y	y	y	4,081	y	y	y	y
66	41	0	y	y	y	y	y		y	y	y	y
67	25	y	Big Lime	Per	DC	Por	2,320	2,395	25	A	Permian	4,528
68	28	y	Big Lime	Per	DL	Por	2,250	2,300	30	A	Permian	4,610
69	25	y	Big Lime	Per	DL	Por	2,060	2,150	y	A	Permian	2,176
70	37	y	Shipley-Hazlett	Per	S	Por	2,550	2,570	7	y	Permian	2,600
71	34	y	Estes sand	Per	S	Por	2,450	2,950	15	A	Permian	3,000
72	32.7	y	Big Lime	Per	DL	Por	2,878	2,952	74	A	Big Lime	3,085
73	29	y	Delaware sand	Per	S	Por	4,665	4,675	5	T	Permian	4,692
74	36	y	O'Brien sand	Per	SD	Por	2,500	2,700	y	ML	Permian	4,825
75	33	y	O'Brien sand	Per	S	Por	2,300	2,525	40	ML	Permian	4,825
76	32	y	Shipley Ls	Per	D	Por	3,075	3,100	10	A	Permian	4,400
77	26	y	Whitehorse Ls	Per	D	Por	3,100	3,170	40	A	Permian	3,175
78	33	y	O'Brien sand	Per	S	Por	2,833	3,100	40	AC	White Horse Ls	3,145
79	30.5	y	O'Brien sand	Per	S	Por	3,100	3,200	22	AC	San Andres	3,855
80	28	1.4	Big Lime	Per	D	Por	2,600	2,900	y	A	Permian	3,920
81	30	y	Big Lime	Per	DL	Cav	3,025	3,075	30	A	Permian	3,450
82	34	y	Permian sand	Per	DL	Por	2,825	3,050	10	A	Permian	3,414
83	36	y	Colby sand	Per	S	Por	3,215	3,313	98	AD	Permian	3,702
84	36.5	y	Keystone Ls	Per	DL	Por	3,210	3,360	150	AD	Permian	3,702
85	28	y	Big Lime	Per	DL	Cav	3,000	3,100	y	A	Permian	3,780
86	35	y	O'Brien (Yates?) sand	Per	S	Por	2,860	3,400	35	MC	Permian	3,565
87	35	y	O'Brien sand	Per	S	Por	3,100	3,200	30	AD	Permian	4,463
88	31	y	Big Lime	Per	DL	Por	5,050	5,260	45	MC	Permian	5,255
89	30	y	Big Lime	Per	DL	Por	y	5,225	y	y	Permian	y
90	30	y	Big Lime	Per	DL	Por	y	5,275	y	y	Permian	5,275

No. 1 Lehn in August. Total depth was 1743 ft. and the initial production 13 bbl. The producing horizon is the "sandy lime zone" of the upper Permian. Several additional small wells have been completed but the pool can be of only moderate importance.

Opp Field.—Harold B. Opp's No. 1 J. T. Jackson, sec. 41, bl. LL, Schleicher County, was completed in September for a 105-bbl. well. The depth was 4060 ft. and production was obtained from a horizon in the Cisco series of Permian age. The importance of the strike cannot be judged at the present time.

Page Field.—First oil production in the Page gas field was found in June by the Lone Star Gas Company's No. 1 Page, sec. 30, bl. L., Schleicher County. Initial production was 250 bbl. of 42° gravity oil at a depth of 5727 to 5747 ft. The producing horizon probably belongs to the Strawn series of the lower Pennsylvanian.

North Cowden Field (Holt Pay).—In the important North Cowden oil field a new and deeper Permian lime producing horizon was discovered by the Gulf Refining Company's No. 1 Holt, which was completed in July 1939. The well made 217 bbl. per day from moderately porous limestone at 5148 to 5186 ft. The gravity of the oil was 35° and the quality was similar to the regular Permian lime production of the district. The new horizon is amost 1000 ft. below the regular pay zone of the field. While two additional small wells had been completed in it by the end of the year, its importance is still problematical.

Conclusions

Although the record of West Texas in 1939 was not as satisfactory as in some former years, the district still has enormous proven reserves, which could maintain production at something like the present level for many years. Many hundreds of proven locations remain to be drilled, of which a considerable number will furnish wells of large size. The search for deeper horizons has just begun and much exploration of this kind can be anticipated for the future. The development of new Ordovician production in northern Pecos County and adjoining areas may possibly assume real magnitude. While West Texas operations are now suffering considerably from the low rate of income, the district is one of the most substantial producing areas in the world and undoubtedly will continue to see a sound development.

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Oil and Gas Development in West Virginia during 1939

By David B. Reger,* Member A.I.M.E.

(New York Meeting, February 1940)

The discovery of prolific oil wells in old territory hitherto regarded as doubtful, if not worthless, and the rapid extension of a gas pool opened late in 1938 were the most interesting petroleum features in West Virginia during 1939. Oil activity in general was slow because of crude prices that were still fairly low at the end of the year, although substantially increased above those in January. Fewer oil wells were completed, but the average results were better than in 1938. Fewer gas wells, also, were completed, with greatly lessened average initial production. Many old oil and gas wells were abandoned, so that the total number of active wells has not changed appreciably. The account of operations, as gathered from trade journals and other sources, shows that 561 new wells were drilled, resulting in 101 new oil wells with 2261 bbl. of daily initial production; 366 new gas wells with 602,400,000 cu. ft. of daily open flow; and 94 dry holes. Besides these new wells, 61 old wells were drilled to deeper sands, with 12 bbl. and 13,328,000 cu. ft. of added production. On the new wells the oil average was 22.38 bbl. per well per day; and the gas average was 1,645,900 cu. ft. per well per day; the ratio of dry holes to completions was 16.76 per cent.

From an exploratory standpoint one partly discredited oil area was revived by good new production, and another small oil pool may have been opened. Some of the results in gas exploration will require more drilling for true appraisal. It is certain, though, that one very considerable gas field in the sands of Mississippian age has been proved; and there is a probability of six new pools in the Middle Devonian shale. In the Oriskany sand (L. Dev.) the Elk-Poca pool has been extended considerably farther northwest into Jackson County; and farther north in Jackson County two widely separated wells, which may be pool openers, have been successfully completed. On the other hand, several important wildcats in various counties have been dry. Stratigraphically lower, some additional wells have been completed in the Newburg sand (Sil.) and one small producer has been completed in the Clinton sand (Sil.), the importance of which can scarcely be overestimated, because no Clinton production has previously been found in the state, although at least seven wells have been drilled through the sand.

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The principal oil wells completed, by counties, were: Calhoun, 10; Gilmer, 6; Pleasants, 17; Ritchie, 21; Roane, 16; Wirt, 6; and Wood, 5. Production for the year was estimated by the U. S. Bureau of Mines as 3,570,000 bbl. The leading counties in gas-field completions were: Boone, 12; Braxton, 11; Cabell, 30; Calhoun, 27; Clay, 24; Gilmer, 32; Jackson, 13; Kanawha, 73; Lincoln, 17; Ritchie, 27; Roane, 20; Wayne, 21; and Wetzel, 15. Production for the year is estimated at 147,000,000,000 cu. feet.

No pipe lines of consequence were built, but a considerable amount of construction for dehydration and desulphurization of gas has been done. The price of gas has remained stationary, but the price of crude oil has increased. Various important mergers of affiliated companies have been concluded. There is a good possibility that a considerable increase in gas exports to Pennsylvania will occur in 1940.

General State of Industry

No exact figures relative to the amount of land under lease in the state are available. One year ago the writer estimated that 4,500,000 acres might be under lease. In 1939 some new territory was leased, but a considerable acreage was surrendered, so that the total figure is not much changed. The proved oil reserve has not been appreciably changed, but the proved gas reserve was increased.

Up to the end of 1939 there had been completed about 63,400 oil and gas wells. During the year 101 oil wells and 366 gas wells were completed, and 786 old wells were abandoned. At the end of the year about 17,953 oil wells and around 13,451 gas wells were active. Production statistics are as follows:

Period	Oil, Bbl.	Average Oil per Well Daily, Bbl.	Gas, Millions Cu. Ft.	Average Gas per Well per Day, Cu. Ft.
To end of 1939	410,091,000		6,484,800	
During 1938	3,684,000[a]	0.57	134,342[a]	30,630
During 1939	3,570,000[a]	0.54	147,000[b]	29,941

[a] Figures by U. S. Bureau of Mines, final for gas, subject to revision for oil.

[b] Estimated by D. B. R.

Principal Areas of Activity

In Boone County, besides routine operations, a well on the western slope of the Warfield anticline was drilled to depth of 6004 ft., with gas in the Big Lime (L. Mis.), Newburg sand (Sil.) and Clinton sand (Sil.). Total open flow was only 418,000 cu. ft., but the rock pressure was 1955 lb.; 169,000 cu. ft. of the gas was found in the two Silurian sands, of which 70,000 cu. ft. occurred in the Clinton. This is the first Clinton sand production found in West Virginia and may easily presage an extensive drilling campaign along the 50-mile portion of this anticline from the well westward through Boone, Logan and Mingo Counties, where the drilling depth should seldom exceed 6000 ft. and should not be more than 4500 ft. in some localities.

In Braxton County, in Birch district, the territory that may now be called the Sleith gas pool continued to be active. In this pool there are 38 gas wells, 1 oil well, 6 dry holes, and 4 drilling wells. Gas production is mainly in the Salt (L. Pen.) and Big Injun (L. Mis.) sands, with average open flows of about 400,000 cu. ft. and average rock pressures of about 525 lb. The productive territory should include at least 8000 acres. The Villa Nova gas pool, partly in the same county and district, will be discussed under Clay County, in which it principally occurs.

In Cabell County, 30 wells out of 31 completions were gas wells, but the average initial production was small. Three of these wells (Clay No. 1 in Barboursville district near Martha; Robinson No. 1-30 in Guyandot at Wilson; and Topping No. 1 in Guyandot southward from Reid), may result in separate pools in the Brown shale zone or may together form a larger pool.

In Calhoun County the 41 completions resulted in 10 oil wells, 27 gas wells and 4 dry holes. One oil well, in the Big Injun sand (L. Mis.), with 35 bbl. of initial production, may open a small pool southeast of Sycamore, Sherman district.

In Clay County 24 wells out of 28 completions obtained oil or gas production. An important feature in this county is a new producing area that may be called the Villa Nova gas pool, along Elk River, partly in Buffalo and Otter districts, Clay County, and partly in Birch district, Braxton County. On the basis of incomplete information, the producing horizon of the discovery well, drilled late in 1938, was described by the writer one year ago as the Webster Springs sand. The complete logs that are now available on various wells show rather conclusively that production is found in the Edray sand rather than in the Webster Springs. The Edray sand, named at its Pocahontas County outcrop by the writer, is in the Pencil Cave (Lillydale) shale of the Mauch Chunk series (U. Mis.) and belongs slightly below the Little Lime (Glenray) of the Mauch Chunk and slightly above the Big Lime of the Greenbrier (L. Mis.) series. Production has not commonly been found in it. Incidentally, an old well drilled in Birch district, Braxton County, one mile northwest of Glendon as of 1916, had 100,000 cu. ft. of gas in the same sand and would have been the discovery well of the Villa Nova pool if this promising showing had been followed.

The Villa Nova pool has 17 producing wells, with gas mostly in the Edray sand, at depth of 1500 to 1800 ft., depending on the topography, but partly in the Rosedale Salt (L. Pen.), Big Lime and Big Injun sand (L. Mis.). Average initial open flow is 1,100,000 cu. ft. per well per day and average rock pressure is 525 lb. There are 16 wells drilling and no dry holes. About 1500 acres of territory have been proved and the pool is yet undefined. This pool is at the extreme northeastern end of the Hansford anticline.

In Gilmer County, 52 completions resulted in 6 oil wells, 32 gas wells and 14 dry holes, all of which may be termed as routine drilling.

In Jackson County 15 wells were drilled, all to the deep Oriskany sand (L. Dev.), as will be separately discussed later.

In Kanawha County 73 gas wells, mostly in the Oriskany sand, were completed, as will be discussed later.

In Lincoln County 17 new gas wells were drilled and 21 old ones were deepened to the Brown shale (M. Dev.), with good results.

In Pleasants County 17 new oil wells had a total measured initial of 457 bbl. and 2 deepened wells added 59 bbl. To a considerable extent this production came from the Big Injun and Squaw sands (L. Mis.), as will be more fully discussed under Ritchie County. A deep well (Ella Hammett), drilled through the Oriskany sand on the Burning Springs anticline in Grant district ½ mile southeast of Eureka, was a failure in the Oriskany but made 3 bbl. of oil in the Speechley(?) sand (U. Dev.).

In Putnam County two new Brown-shale (M. Dev.) gas wells (Oxley No. 1 and Glass No. 1), in Curry district east of Frank, have opened a new productive zone on the Byrnside anticline, where former gas has mainly been found in the Salt sand (L. Pen.). The good structure of this locality holds considerable promise.

In Ritchie County 21 new oil wells totaled 1217 bbl. of new production. To a large extent this production comes from the Squaw sand (L. Mis.) in the Buck Run oil pool, which is astride the Ritchie-Pleasants line 3 miles south of Schultz. These wells have revived an old producing locality where earlier drilling had not been very successful. The largest well (S. C. Hammett, 3720) on the Ritchie side of the line made 520 bbl. after a shot. In this county, also, 27 new gas wells and 5 wells drilled deeper yielded 9,555,000 cu. ft. of new open-flow gas production.

In Roane County 44 completions resulted in 16 oil wells with 184 bbl. of new production, 20 gas wells with 9,078,000 cu. ft. of daily open flow, and 8 dry holes.

In Wayne County 21 new gas wells yielded 5,842,000 cu. ft. of daily open flow. One of these wells (Booth No. 1), in Butler district southwest of Wayne, had Newburg sand (Sil.) production. A wildcat (Hutchinson No. 1), in Ceredo district south of Ceredo, was dry through the Oriskany sand. Another well (Smith No. 1), in Union district north of Herbert, apparently opens up some new Brown-shale territory.

In Wetzel County 15 new wells and 2 old wells drilled deeper gave 22,468,000 cu. ft. of new daily open-flow gas production

SUMMARY OF EXPLORATION

Table 1 gives a summary of important wildcat or exploratory wells drilled during 1939, together with some others that have furnished unexpected production in old fields.

DEVELOPMENT IN ORISKANY SAND

Drilling to the deep Oriskany sand (L. Dev.) in 1939 was mainly confined to Jackson and Kanawha Counties. The results so far obtained in these two counties are summarized in Table 2. This table, incidentally, has been revised because of more information on wells completed before 1939 and does not entirely agree with previous summaries. In Jackson County 15 wells were drilled to the Oriskany, resulting in 13 gas producers with 86,197,000 cu. ft. of new open flow daily. Most of these wells are in Ripley and Washington districts and are northwestern outposts of the Elk-Poca field of Kanawha County. One of the new wells (Parsons No. 1), however, is in the northern part of Ripley district, 3 miles east of Ripley town and 15 miles north of the Elk-Poca pool. It may therefore open a new pool. Another new well (Currey No. 1) is in the northern edge of Ravenswood district, west of Buttermilk, and is likewise far removed from older production. Two completions in the vicinity of Ravenswood city, Ravenswood district, in 1938 and 1939 seem to point to another producing area. These four definitely productive localities will no doubt result in a considerable drilling campaign. Two wildcats in Ripley district (Starr No. 1, north of Silverton, and Lathey No. 1, northeast of Rockcastle), on the other hand, may discourage drilling in the southwestern region. As of Jan. 1, 1940, in this county 12 wells were drilling or unreported.

In Kanawha County the Oriskany operations have mostly reached a routine stage. Two wildcats in Washington district (Wiseman No. 1, south of Upper Falls, and Toney No. 1, north of Alumville) were dry in the Oriskany, although having small flows in the Brown shale. The Wiseman well was formerly reported by the writer as a 1938 dry hole in the Oriskany, but its recorded completion date should be 1939. These two wells, however, may open a productive Brown-shale area. The total figures for the Oriskany sand in this county in 1939 show 57 completions, with 55 gas wells having 349,056,000 cu. ft. of new open flow daily, and 2 dry holes. As of Jan. 1, 1940, 38 Oriskany wells were drilling or unreported. Some of the unreported wells may be abandoned locations.

The figures shown in Table 2 refer only to results in the Oriskany sand. Various wells in the Campbell-Davis Creek and Elk-Poca pools of Kanawha County, planned as Oriskany tests, have been completed as gas wells in higher sands, mainly the Salt sand (L. Pen.), Big Lime (L. Mis.) and Brown shale (M. Dev.). One of these wells (Morton No. 2), in Poca district, had a Big Lime open flow of 17,280,000 cu. ft. per day.

Any attempt to define the producing limits of the Oriskany sand in Jackson County would be pure conjecture. The quantity of gas per acre or per well in the recently completed wildcats would likewise be impossible to estimate, but the wells of the southern parts of Ripley and Washington districts belong to the Elk-Poca pool and may be expected to conform with that field in production.

In the Charleston gas field, which may be defined as including the Campbell-Davis Creek, Cooper Creek, and Elk-Poca pools, with about 65,000 acres of proved Oriskany gas, it is estimated that about 200,000,000,000 cu. ft. of gas has been produced. Rock pressures, originally varying from 1000 to 2000 lb., have now declined to 250 or 300 lb. in the

TABLE 1.—*Important Wildcats Drilled in West Virginia during* 1939

No.	County	Magisterial District	Location		Total Depth, Ft.	Surface Formation
			Lat.	Long.		
1	Boone	Peytona	2.25 mi. S. of 38° 15′	3.94 mi. W. of 81° 35′	6,004	Pen.-Kanawha
2	Boone	Washington	2.99 mi. S. of 38° 00′	3.61 mi. W. of 81° 45′	1,428	Pen.-Kanawha
3	Cabell	Barboursville	1.98 mi. S. of 38° 25′	1.54 mi. W. of 82° 15′	3.258	Pen.-Conemaugh
4	Cabell	Guyandot	5.58 mi. S. of 38° 30′	0.20 mi. W. of 82° 20′	2.955	Pen.-Conemaugh
5	Cabell	Guyandot	2.32 mi. S. of 38° 25′	2.50 mi. W. of 82° 20′	3,308	Pen.-Conemaugh
6	Calhoun	Sherman	0.04 mi. S. of 38° 50′	0.05 mi. W. of 81° 05′	2,257	Perm.-Dunkard
7	Jackson	Ravenswood	3.20 mi. S. of 39° 00′	3.47 mi. W. of 81° 40′	4,741	Perm.-Dunkard
8	Jackson	Ravenswood	2.13 mi. S. of 39° 00′	3.59 mi. W. of 81° 35′	4,707	Perm.-Dunkard
9	Jackson	Ripley	0.92 mi. S. of 38° 45′	1.09 mi. W. of 81° 45′	5,023	Perm.-Dunkard
10	Jackson	Ripley	0.29 mi. S. of 38° 50′	4.03 mi. W. of 81° 35′	5,139	Perm.-Dunkard
11	Kanawha	Poca	3.32 mi. S. of 38° 35′	4.51 mi. W. of 81° 35′	1,799	Pen.-Monongahela
12	Kanawha	Washington	2.81 mi. S. of 38° 20′	0.73 mi. W. of 81° 45′	4,780	Pen.-Conemaugh
13	Pleasants	Grant	3.43 mi. S. of 39° 25′	1.11 mi. W. of 81° 15′	5,311	Pen.-Monongahela
14	Putnam	Curry	4.73 mi. S. of 38° 25′	0.16 mi. W. of 81° 55′	4,379	Pen.-Monongahela
15	Putnam	Curry	0.12 mi. S. of 38° 20′	0.65 mi. W. of 82° 55′	4,038	Pen.-Conemaugh
16	Ritchie	Grant	3.48 mi. S. of 39° 20′	3.41 mi. W. of 81° 10′	2,006	Perm.-Dunkard
17	Ritchie	Grant	3.39 mi. S. of 39° 20′	3.41 mi. W. of 81° 10′	1,982	Perm.-Dunkard
18	Ritchie	Grant	3.61 mi. S. of 39° 20′	3.37 mi. W. of 81° 10′	2,025	Perm.-Dunkard
19	Wayne	Butler	3.39 mi. S. of 38° 15′	3.84 mi. W. of 82° 25′	3,793	Pen.-Conemaugh
20	Wayne	Butler	3.38 mi. S. of 38° 15′	4.15 mi. W. of 82° 25′	3,748	Pen.-Conemaugh
21	Wayne	Ceredo	3.99 mi. S. of 38° 25′	1.47 mi. W. of 82° 30′	3,136	Pen.-Conemaugh
22	Wayne	Union	3.32 mi. S. of 38° 20′	2.40 mi. W. of 82° 25′	2,903	Pen.-Conemaugh

Campbell-Davis Creek and Cooper Creek pools but grade upward to about 1900 lb. along the northwestern extension of the Elk-Poca pool in Jackson County. It would now appear that the field, as presently proved, but not entirely developed, should have an ultimate Oriskany production of about 400,000,000,000 cu. ft., or an average of about 6,000,000 cu. ft. per acre. About one-half of this gas has already been recovered. In view of the line pressures of 200 or 250 lb., against which many of the wells operate, it would further appear that field pumping plants may soon become necessary.

To take care of the sulphur that has appeared in various wells in the northern part of the Elk-Poca pool, four Girdler-process (Girbotol) desulphurization and dehydration plants have been built by the following operators, with respective daily capacities: United Fuel Gas Co., 50,000,000 cu. ft.; Columbian Carbon Co., 30,000,000 cu. ft.; Godfrey L. Cabot, Inc., 15,000,000 cu. ft.; South Penn Oil Co., 15,000,000 cu. ft.

TABLE 1.—(*Continued*)

No.	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day		Tubing or Casing Pressure, Lb. per Sq. In.	Remarks
				Oil, Bbl.	Gas, M Cu. Ft.		
1	Sil.-Clinton	Owens-Libbey-Owens Gas Dept.	Bull Creek Coal Land Co., 13-500	0	418	1,955 (120 hr.)	Big Lime, Newburg, & Clinton gas well
2	U. Mis.-Mauch Chunk	Ottawa Gas Co.	Mary F. Ellis, et al., 1	0	3,645	550 (24 hr.)	Morton gas well
3	M. Dev.-Shale	Summit Gas & Dev. Co.	William N. Clay, 1	0	220	550 (48 hr.)	Berea and Brown-shale gas well
4	M. Dev.-Shale	Merritts Creek Gas Co.	W. L. Robinson, 1-30	0	130	?	Brown-shale gas well
5	M. Dev.-Shale	Four Pole Gas Co.	Virgil M. Topping, 1	0	52	420 (72 hr.)	Brown-shale gas well
6	L. Mis.-Pocono	Hamilton & Coleman	T. S. Cunningham, 1	35	?	?	Big Injun oil well
7	L. Dev.-Oriskany	Joe Rubin	R. G. Starr, 1	0	0	0	Dry; Oriskany absent
8	L. Dev.-Oriskany	Joe Rubin, N. P. Johnston, et al.	D. P. Currey, et al., 1	0	2,534	1,900	Oriskany gas well
9	L. Dev.-Oriskany	Columbian Carbon Company	G. W. Lathey, et al., 1-GW423	0	0	0	Dry through Oriskany
10	L. Dev.-Oriskany	Columbian Carbon Company	John F. Parsons, 1-GW429	0	328	1,870 (40 hr.)	Oriskany gas well
11	L. Mis.-Greenbrier	Godfrey L. Cabot, Inc.	D. H. Morton, 2-925	0	17,280	635 (24 hr.)	Big Lime gas well
12	L. Dev.-Oriskany	Owens-Libbey-Owens Gas Dept.	John P. Toney, et al., 1-558	0	147	?	Dry in Oriskany; Brown-shale gas at 3,396–3,950 ft.
13	L. Dev.-Oriskany	Columbian Carbon Company	Ella Hammett, et al., 1	3	3	?	Dry in Oriskany; plugged back to Speechley at 2,930 ft.
14	M. Dev.-Shale	Reishman Oil & Gas Co.	M. L. Oxley, 1	0	368	800 (24 hr.)	Brown-shale gas well
15	M. Dev.-Shale	Reishman Oil & Gas Co.	Wm. Glass (W. G. May), 1	0	293	755 (24 hr.)	Brown-shale gas well
16	L. Mis.-Pocono	G. S. M. Powell Farm Oil Co.	D. P. Carder, 3	300	?	?	Squaw oil well
17	L. Mis.-Pocono	Hope Const. & Ref. Co.	S. C. Hammett, 3,720	520	?	?	Squaw oil well
18	L. Mis.-Pocono	Schultz Oil Co.	T. C. Hammett Hrs., 6	200	?	?	Squaw oil well
19	Sil.-Newburg	Chartiers Oil Co.	Wilson & I. J. Buskirk, 1	0	400	1,390 (12 hr.)	Newburg gas well
20	Sil.-Newburg	Chartiers Oil Co.	Burnie Booth, 1	0	260	?	Newburg gas well
21	L. Dev.-Oriskany	Fairfax Oil & Gas Co.	S. T. Hutchison, 1	0	0	0	Dry through Oriskany
22	M. Dev.-Shale	Industrial Gas Corp.	J. D. Smith, 1	0	168	?	Brown-shale gas well

In other counties, outside of Jackson and Kanawha, the deep tests of 1939 made no Oriskany-sand gas, although some of these wells were otherwise productive. These include one well in Boone, one in Pleasants, and three in Wayne County. Only a few such tests are drilling in the state but two important tests on the Laurel Hill anticline in Fayette County, Pa. and on the Accident Dome in Garrett County, Md., may indicate the Oriskany probabilities of Monongalia, Preston, Tucker and other northern West Virginia Counties.

Table 2.—*Oriskany Sand Wells, Jackson and Kanawha Counties, W. Va.*

County and Magisterial District	Completed before 1939				Completed in 1939				Total Number of Completed Wells	Number of Wells Drilling or Unreported, Jan. 1, 1940
	Gas Wells		Dry in Oriskany	Total Number of Wells	Gas Wells		Dry in Oriskany	Total Number of Wells		
	Number of Wells	Gas, M Cu. Ft.			Number of Wells	Gas, M Cu. Ft.				
Jackson County:										
Grant	0	0	0	0	0	0	0	0	0	2
Ravenswood	1	337	1	2	2	2,932	1	3	5	0
Ripley	2	12,795	1	3	6	39,817	1	7	10	6
Washington	1	5,329	2	3	5	43,448	0	5	8	4
Total	4	18,461	4	8	13	86,197	2	15	23	12
Kanawha County:										
Big Sandy	0	0	1	1	0	0	0	0	1	0
Cabin Creek	0	0	3	3	0	0	0	0	3	0
Charleston	1	88	0	1	0	0	0	0	1	0
Elk	84	361,356	10	94	5	11,025	0	5	99	7
Jefferson	0	0	1	1	0	0	0	0	1	0
Loudon	8	3,788	5	13	0	0	0	0	13	1
Malden	35	73,181	5	40	0	0	0	0	40	2
Poca	153	1,623,116	1	154	50	338,031	0	50	204	21
Union	10	21,918	0	10	0	0	0	0	10	7
Washington	0	0	0	0	0	0	2	2	2	0
Total	291	2,083,447	26	317	55	349,056	2	57	374	38
Grand total	295	2,101,908	30	325	68	435,253	4	72	397	50

Operating Technology

In the Charleston gas field, Columbian Carbon Co. has installed Blaw-Knox individual dehydration plants at several gas wells. These plants, which are experimental in character and not reported in use elsewhere, are prefabricated in units of 2,000,000 cu. ft. daily capacity, in which the dehydrating solution contacts the gas under pressure and is then recycled under a pressure of 500 lb. A well having more than 2,000,000 cu. ft. of flow into the pipe line would, of course, require two or more units.

Some good results from the acid treatment of Big Lime gas wells continue to be reported. One well in southern Wayne County, for instance, with an original open flow of 2,236,000 cu. ft., which later declined to small quantity, was treated with 1000 gal. and increased to 4,950,000 cu. feet.

PIPE LINES AND MARKETS

Few new pipe lines of any consequence were constructed. In Kanawha County Godfrey L. Cabot, Inc., built an 8-in. loop gas line from the Campbell Creek territory northwest 10 miles to Edgewood, a northern suburb of Charleston. In the same county Ajax Gas Co. built a small gas line from Sissonville south 15 miles to Dunbar.

Crude-oil prices and demand have considerably increased. Starting with a low of $1.28 per barrel as of Jan. 1, successive increases carried the posted price of $2.34. These increases will greatly help the owners of small oil wells and will give some encouragement for drilling in favored localities.

According to the U. S. Bureau of Mines, the field, or well-mouth price of gas steadily declined from 1931 to 1937. The figure for 1938 is 13.0¢ per M cu. ft., a rise of 0.1¢ over the 1937 price of 12.9¢. No price or value figure is available for 1939, but there has been little change.

CORPORATE CHANGES

Late in 1939 numerous corporate changes, mainly in the way of mergers of affiliated operating units, took place among the larger oil and gas companies of the state. Hope Natural Gas Co. absorbed Reserve Gas Co., a subsidiary, and will now operate both properties. In the latter half of February, Hope is scheduled to move its executive offices from Pittsburgh, Pa., to Clarksburg, W. Va., where a large operating office has been maintained for many years.

Clayco Gas Co., a subsidiary of South Penn Oil Co., has changed its name to South Penn Natural Gas Co. To this new company South Penn Oil Co. has conveyed all its West Virginia properties and business except its Morgantown tank farm, two blending stations, and its marketing facilities. South Penn Oil Co. will retain its charter name but will pass out of the picture as an operating company in West Virginia, where it has long been most prominent.

Columbia Gas and Electric Corporation will greatly simplify its financial structure, if public authorities approve its plans. Its subsidiary, Manufacturers Light & Heat Co., operating from Pittsburgh, will absorb Cumberland and Allegheny Gas Co. and Natural Gas Company of West Virginia and will therefore have full charge of all company operations in northern West Virginia. Another subsidiary, United Fuel Gas Co., operating out of Charleston, will expand its scope by absorbing Warfield Natural Gas Co., which heretofore has handled Kentucky drilling operations. Huntington Development and Gas Co. will continue to operate separately as before.

COUNTY SUMMARY

Table 3 shows by counties the new development in West Virginia during 1939. This information is compiled from all available sources, including the trade journals, the West Virginia Department of Mines, the West Virginia Geological Survey, the special Plat Service afforded to the industry on a commercial basis by Veleair C. Smith, Management, and

TABLE 3.—*Summary of New Development in West Virginia during* 1939

County	New Wells						Wells Drilled to Deeper Sands			
	Number of Wells	Oil Wells		Gas Wells		Dry Holes	Number of Wells	Production		Dry Holes
		Number of Wells	Bbl. per Day	Number of Wells	M Cu. Ft. per Day			Oil, Bbl. per Day	Gas, M Cu. Ft. per Day	
Barbour	1	0	0	1	184	0	0	0	0	0
Boone	13	0	0	12	10,111	1	2	0	610	0
Braxton	17	0	0	11	6,389	6	0	0	0	0
Brooke	4	3	15	0	0	1	0	0	0	0
Cabell	31	0	0	30	5,143	1	1	0	95	0
Calhoun	41	10	172	27	11,076	4	0	0	0	0
Clay	28	2	51	24	25,068	2	1	0	330	0
Doddridge	6	2	17	3	728	1	5	0	803	0
Fayette	1	0	0	1	738	0	0	0	0	0
Glimer	52	6	40	32	12,684	14	3	0	941	1
Hancock	5	3	9	0	0	2	0	0	0	0
Harrison	1	0	0	1	136	0	4	0	442	0
Jackson	15	0	0	13	86,197	2	0	0	0	0
Kanawha	73	0	0	73	384,915	0	0	0	0	0
Lewis	4	0	0	1	76	3	1	0	0	1
Lincoln	19	1	25	17	4,478	1	21	0	4,658	0
Logan	5	0	0	5	2,086	0	1	0	1,847	0
Marion	4	1	10	3	346	0	4	0	319	1
Marshall	3	1	3	2	176	0	1	5	0	0
Mingo	5	0	0	5	623	0	0	0	0	0
Monongalia	4	1	1	3	1,514	0	2	0	168	1
Pleasants	32	17	457	8	2,309	7	2	2	59	0
Putnam	5	0	0	5	1,610	0	3	0	418	0
Ritchie	64	21	1,217	27	7,355	16	7	5	2,200	2
Roane	44	16	184	20	9,078	8	0	0	0	0
Tyler	13	2	2	3	891	8	0	0	0	0
Upshur	2	0	0	2	525	0	0	0	0	0
Wayne	27	3	8	21	5,842	3	1	0	92	0
Wetzel	19	1	3	15	22,122	3	2	0	346	0
Wirt	12	6	8	0	0	6	0	0	0	0
Wood	10	5	39	0	0	5	0	0	0	0
State total	561	101	2,261	366	602,400	94	61	12	13,328	6

from private reports. The various reports are not in entire agreement, but Table 3 reflects a careful check by individual wells and should not be much in error, unless there has been failure to report certain wells.

According to the Department of Mines, 718 permits were issued, including 30 permits to drill old wells deeper. Of these permits 513 have been reported to the Department as completed. The Department summary, however, does not include any wells completed through 1938 permits. Also, few, if any, of the 135 permits issued in November and December 1939 have become completed wells, but these permits almost exactly balance the 134 permits for the same period in 1938, presumably resulting in 1939 completions. The writer notes a growing tendency among many operators to report to the Department complete logs and complete initial oil and gas tests, although such complete records are not required by law. In view of the great value of such statistics, it is hoped that full cooperation in this particular may soon prevail.

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Argentina's Oil Production in 1939

BY MARIO L. VILLA*

(New York Meeting, February 1940)

DURING 1939 oil production experienced a new and important increase in Argentina in the productive areas of Comodoro Rivadavia (Territory of Chubut), Plaza Huincul (Territory of Neuquén), and those of the Province of Mendoza. Production in the Standard Oil Company's field in the Province of Salta declined, but that of the Government oil fields in that province increased 62.5 per cent.

TABLE 1.—*Oil and Gas Production in Argentina*

Line Number	Field, *Territory or Province*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
	Comodoro Rivadavia, *Chubut Territory*					
1	Zone A	32	10,940	1,000	103,885,268	4,435,733
2	Zone B	15	9,040	6,900	51,467,314	9,327,743
3	Zone C	23	2,860	250	17,191,324	1,012,086
	Zone D	6			24,361	
	Plaza Huincul, *Neuquén Territory*					
5	Zone 1	21	220	120	1,648,992	47,791
6	Zone 2	13	1,440	370	4,089,581	913,653
7	Zone 3	15	560	250	9,567,247	336,137
8	Zone 4	5	40		44,677	1,465
	Province of Salta					
9	Zone Tartagal	13	850		4,546,858	627,955
10	Zone San Pedro	11	370		9,715,822	990,064
11	Zone Agua Blanca	13	110		959,558	91,859
	Province of Mendoza					
12	Zone Cacheuta	8	350		195,229	87,890
13	Zone Tupungato	6	270		838,089	716,619
14	Zone El Sosneado	14	50		261,079	6,485
15	Zone Ranquil-có	1	*x*		1,904	1,904
16	Zone Lunlunta	1	*x*		1,209	1,209

[b] Footnotes to column heads and explanation of symbols are given on page 239.

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Comodoro Rivadavia produced a total of 14,789,463 bbl., which, compared with last year's 14,110,608 bbl., represents an increase of 4.8 per cent. This increase belongs to the normal development programs of the already proven fields, as in 1939 no new field was developed. Figures in Table 3 show the steady increase of the field's output, from 101 bbl. produced in the first year of development to 14,789,463 bbl. in 1939.

Plaza Huincul, owing to intense development work carried out in zone 2, reference to which was made in last year's report (*Trans.* A.I.M.E., vol. 132), registered an increase of 31.6 per cent in production. In that area Y.P.F. and Compania La República Ltd. are operating, so that such increase may be credited to both (Table 3).

In the Province of Salta intensive development operations in the southern area of the Tranquitas field, in the region known as Tartagal, have brought about for Y.P.F. a 62.5 per cent increase over last year's output, representing a total of 188,845 bbl. of crude.

Y.P.F. has sunk five more wells in the Río Pescado area (Aguas Blancas) which are good producers. In all, nine wells have been drilled by the Government in this new field and as soon as the necessary field equipment has been installed exploitation will be intensified. This work

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.	Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells					
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Avg. at End of 1939		Gravity A.P.I. at 60° F., Weighted Average	Sulphur, Per Cent
1	164,565	8,327.3	2,473	78	44	139	1,425	20	19	1,406	y	RP	20.7	
2	58,107.4	3,558.4	800	124	11	93	480	25	8	472	458.7	PM	24.2	
3	10,712.9	828.9	760	50	29	173	359	24		359	x	PM	19.0	
4	x	x	11			3		2			x		23.1	
5	1,747.3	194.4	103			10	49			49	x	RP	30.7	
6	7,847.2	1,313.6	167	14	10	37	115	7	19	96	727	PM	35.4	
7	9,647.5	437.7	213		11	45	101	6		101	x	RP	33.6	
8			11	1	1	2					x		38.4	
9	6,876.4	987.4	207	10	1	43	126			126	720	PM	45.4	
10	10,466.5	1,246.2	65			21	28		21	7	x		44.5	
11	21.2		22	5		10	6		1	5	1,992	PM	47.9	
12	60.4	60.4	43			2	25		1	24			31.6	
13	218.4	218.4	17	4		6	10		10		3,329		33.3	
14			14			14					x		12.9	
15			2	1	1		1			1	x		13.5	28
16			2	1			1		1		4,266		29.2	

involves the construction of a 25-km. pipe line, a terminal shipping plant for railroad tank cars, a compressor plant for gasoline extraction and pressure-maintenance operations, and a stabilizing and storage plant. Table 3 shows Salta's crude output since 1926, the year in which development began.

The Province of Mendoza showed an outstanding increase in its crude production for 1939, for which the four new wells drilled by Y.P.F. are responsible. These have become good producers, confirming the first impression that a new field of great importance had been discovered. A new horizon, known as the Tupungato horizon, contributed in 1939 a crude output of 712,343 bbl. from three wells. One of these wells was finished in April, another in August, a third in October and a fourth on Dec. 31 (the last, of course, cannot be taken into account), and are not producing to full capacity, flowing through $\frac{7}{32}$ to $\frac{9}{32}$-in. openings. Table 3 gives Mendoza's yearly output figures since 1926, the year in which development began.

The country's total crude production in 1939 amounted to 18,613,167 bbl., of which 10,222,533 bbl. were from Government oil fields. Compared with 1938 this means an increase in the country's production

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Glauconitico y Chubutiano	CreU	S	28	1,640–2,300	1,800–3,940	30	AF	Chubutiano	7,750
2	Glauconitico y Chubutiano	CreU	S	25	2,620–4,920	2,690–6,400	36	AF	Chubutiano	6,389
3	Glauconitico y Chubutiano	CreU	S	28	1,640	2,130	13	AF	Chubutiano	4,133
4	Chubutiano	CreU	S	20	2,890	2,920	26	A	Chubutiano	6,616
5	Dogger	Jur	S	Por	1,870	1,990	39	MU	Liásico	3,011
6	Dogger	Jur	S	20–29	2,370	2,500	33	MU	Liásico	5,320
7	Dogger	Jur	S	Por	2,400	2,590	56	MU	Liásico	4,202
8	Dogger	Jur	S	18	3,362	3,665		MU	Liásico	5,038
9	Areniscas superiores, Calcáreo y Gondwana	Cre? Por	S-LS	12–20	1,150	1,970	33	A	Gondwana	6,035
10	Gondwana y Devónico	Per-Dev	S	Por			30	A	Devónico	3,920
11	Areniscas superiores, y Gondwana	Cre? Per	S	12–22	3,370	4,260	40	A	Gondwana	5,182
12	Victor, Cacheuta y Potrerillos	Tri	S	Por	1,940	3,080	13	MUP AF	Serie Porfiritica	4,303
13	La Pilona Victor	Ter Tri	HS S	Por	740 5,870	1,400–6,510		A	Victor	7,055
14	y	Ter-CreL						MI		
15	Neocomiano	CreL	LS		930	1,220		A	Serie Porfiritica	3,599
16	Potrerillos	Tri	S	Por	7,386	7,426	39	A	Potrerillos	8,121

amounting to 1,537,018 bbl. (9 per cent), of which 1,224,153 bbl. (13.6 per cent) must be credited to Y.P.F. and the remainder (3.8 per cent) to private companies. The amount of crude produced by each company in 1939 is given in Table 4.

In the Lunlunta region, Province of Mendoza, 30 km. east of the Cacheuta field, Y.P.F. in 1936 drilled a wildcat that reached a depth of 8121 ft. and found only oil and gas shows. In 1939 a new well was sunk at a distance of 4½ km. from the earlier well, tapping an oil sand between 4188 and 4231 ft., from which the well is now flowing.

Y.P.F.'s R.C. 2, drilled in the Ranquil-có area, 320 km. south of the Cacheuta field, discovered another pool between 939 and 1220 ft. comprising four productive sands.

Well S.E. 1, also drilled by Y.P.F. in Mendoza, Santa Elena area, attained a depth of 4920 ft., encountering basement rocks that demonstrate that overthrust faults due to movements of the Cordillera de los Andes extend farther east than was previously thought.

Well N.S. 1, the first drilled in the Senillosa area (Territory of Neuquén), discovered an important gas accumulation. Drilling is still in progress.

TABLE 2.—*Summary of Drilling Operations in Argentina*

Important Wildcats Drilled in 1939

Province or Territory	Location	Well	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
							Oil, Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
Chubut.....	Comodoro Rivadavia	1,656	6,193	Oligocene	Cretaceous	Y.P.F.	157	*x*	2	*x*	*x*	
Chubut.....	Comodoro Rivadavia	M.8	2,139	Eocene	U. Cretaceous	Y.P.F.						Dry hole
Chubut.....	Comodoro Rivadavia	S.132	5,346	Pliocene	U. Cretaceous	Y.P.F.	252	*y*		*y*	*y*	
Neuquén...	Senillosa	NS.1	3,443	U. Cretaceous	L. Cretaceous	Y.P.F.		7		*y*	*y*	
Salta.......	Aguas Blancas	AB.10	3,545	Tertiary	Devonian	Standard Oil Co.						Drilling
Mendoza...	Lunlunta	L.3	7,426	U. Tertiary	Triassic	Y.P.F.	252	0.03	1 5/64	106	21	
Mendoza...	Ranquil-có	RC.2	3,598	U. Cretaceous	Triassic	Y.P.F.	31			*y*	*y*	
Mendoza...	Tupungato	T.22	6,718	U. Tertiary	Triassic	Y.P.F.	2,276	0.8	1 5/32	811	967	
Mendoza...	Santa Elena	SE.1	4,920	Tertiary	Triassic	Y.P.F.						Dry hole
San Luis....	Alto Pencoso	AP.1	2,465	Miocene	Undetermined	Y.P.F.						Dry hole

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	50	8
Number of oil wells completed during 1939	277	2
Number of gas wells completed during 1939	6	2
Number of dry holes completed during 1939	30	14

TABLE 3.—*Crude Production in Argentina*

BARRELS

Year	Government Fields (Y.P.F.)	Private Companies	Total
COMODORO RIVADAVIA			
1907	101		101
1908	11,454		11,454
1909	18,801		18,801
1910	20,713		20,713
1911	13,096		13,096
1912	46,936		46,936
1913	130,411		130,411
1914	275,470		275,470
1915	513,139		513,139
1916	816,316	48,880	865,196
1917	1,142,919	67,095	1,210,014
1918	1,242,734	108,697	1,351,431
1919	1,183,105	145,852	1,328,957
1920	1,424,962	222,282	1,647,244
1921	1,747,406	303,052	2,050,458
1922	2,163,194	667,432	2,830,626
1923	2,516,302	772,230	3,288,532
1924	3,424,068	1,146,107	4,570,175
1925	3,832,321	2,037,155	5,869,476
1926	4,530,328	3,096,221	7,626,549
1927	4,983,970	3,111,028	8,094,998
1928	5,107,046	3,089,315	8,196,361
1929	5,077,370	3,083,956	8,161,326
1930	4,538,814	2,818,719	7,357,533
1931	4,707,040	4,703,719	9,410,759
1932	4,962,175	5,313,232	10,275,407
1933	5,134,407	5,170,619	10,305,026
1934	4,780,513	6,072,781	10,853,294
1935	5,390,694	6,016,259	11,406,953
1936	6,405,101	6,154,916	12,560,017
1937	7,121,444	6,284,731	13,406,179
1938	8,046,797	6,063,811	14,110,608
1939	8,283,496	6,505,967	14,789,463
Totals...	99,592,639	73,007,205	172,599,844
PLAZA HUINCUL			
1918	82		82
1919	126		126
1920	3,843		3,843
1921	5,781		5,781
1922	31,312		31,312
1923	44,898	1,585	46,483
1924	60,095	28,714	88,809
1925	92,866	26,148	119,014
1926	147,790	61,799	209,589
1927	191,914	324,256	516,170
1928	298,976	462,869	761,845
1929	389,055	634,177	1,023,232
1930	565,641	780,532	1,346,173
PLAZA HUINCUL.—(*Continued*)			
1931	640,920	997,305	1,638,225
1932	588,272	1,222,015	1,810,287
1933	417,260	1,014,502	1,431,762
1934	328,634	756,417	1,085,051
1935	386,936	534,512	921,448
1936	496,973	548,312	1,045,285
1937	482,927	502,036	984,963
1938	466,297	520,485	986,782
1939	640,712	658,337	1,299,049
Totals...	6,281,307	9,073,992	15.355,299
SALTA			
1926		1,403	1,403
1927		17,996	17,996
1928	7,177	90,727	97,904
1929	19,530	187,146	206,676
1930	103,747	191,411	295,158
1931	146,934	477,002	623,936
1932	123,152	895,665	1,018,817
1933	237,819	1,670,209	1,908,028
1934	130,499	1,902,977	2,033,476
1935	120,969	1,792,210	1,913,179
1936	209,444	1,562,103	1,771,542
1937	244,838	1,604,478	1,849,316
1938	301,857	1,475,760	1,777,617
1939	490,702	1,219,845	1,710,547
Totals...	2,136,668	13,088,932	15,225,600
MENDOZA			
1926		12,580	12,580
1927		491	491
1928		14,467	14,467
1929		157	157
1930		2,799	2,799
1931		35,369	35,369
1932	1,585	32,651	34,236
1933	8,561	37,180	45,741
1934	16,046	37,029	53,075
1935	36,451	17,253	53,704
1936	60,283	20,826	81,109
1937	86,563	26,078	112,641
1938	183,429	17,713	201,142
1939	807,623	6,485	814,108
Totals...	1,200,541	261,078	1,461,619

In Comodoro Rivadavia, well S. 132, drilled in zone No. 2, has discovered between 5205 and 5297 ft., the deepest pool yet found in this field.

TABLE 4.—*Crude Production by Different Companies*
BARRELS

Company	Comodoro Rivadavia	Plaza Huincul	Salta	Mendoza	Total
Yacimientos Petroliferos Fiscales	8,283,496	640,712	490,702	807,623	10,222,533
Astra	840,803	7,944			848,747
Ferrocarrilera	960,200				960,200
Industrial y Comercial	215,778				215,778
Diadema Argentina	4,206,054				4,206,054
Solano	283,132				283,132
Standard Oil Co		236,026	1,219,845		1,455,871
La República		414,367			414,367
Río Atuel Ltd				6,485	
Totals	14,789,463	1,299,049	1,710,547	814,108	18,613,167

Petroleum in Bahrein Island, 1939*

THE oil production in Bahrein for the year 1939 totaled 7,588,554 bbl., a decline of 709,444 bbl. from the 1939 production of 8,297,998 bbl. The production for the first seven months of 1939 remained fairly constant, the daily average by months during this period ranging between 20,000 and 22,000 bbl. per day. The daily average rose in August to the year's high of 23,800 bbl. per day, then dropped gradually to the year's low of 18,787 bbl. per day for November. The daily average for the year was 20,791 bbl. At the end of 1939 there were 59 wells producing and 8 wells drilling.

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* Information received through the courtesy of the Bahrein Petroleum Company, Ltd. Manuscript received at the office of the Institute May 1, 1940.

Petroleum Developments in Canada in 1939

By G. S. Hume*

(New York Meeting, February 1940)

Production of petroleum and natural gas increased in Canada in 1939 principally because of new wells in Ontario and Alberta.

Turner Valley

The Turner Valley field, Alberta, yielded 7,456,000 bbl. of petroleum in 1939 in comparison with 6,703,548 bbl. in 1938, an increase of 11 per cent. Turner Valley now supplies 96 per cent of all petroleum produced in Canada (Table 1).

Table 1.—*Production of Petroleum and Natural Gas in Canada*

Province	Petroleum, Bbl.		Natural Gas, Thousands Cu. Ft.	
	1938	1939	1938	1939
Alberta	6,742,039	7,500,000	21,792,779	22,775,000
Saskatchewan			87,422	100,000
Manitoba			600	600
Ontario	172,059	207,500	10,696,833	11,700,000
New Brunswick	19,277	18,800	581,832	610,500
Northwest Territories	22,854	17,013		
Total	6,956,229	7,743,313	33,159,466	35,186,100

The Turner Valley field (Table 2) has reached a position where it can supply much larger volumes of petroleum than the Prairie market is capable of consuming. The allowable production is under the jurisdiction of the Petroleum and Natural Gas Conservation Board of Alberta and the daily rate is set from time to time as warranted by the demand. During June the allowable reached a maximum of 27,000 bbl. a day. This, however, was a temporary situation due in part to the completion of a new British American Oil Co. refinery in Calgary capable of processing 5000 bbl. a day and with a storage capacity of about 100,000 bbl. The maximum consumption was reached during the harvest season with

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* Bureau of Geology and Topography, Canada Department of Mines and Resources, Mines and Geology Branch, Ottawa, Ont., Canada.

an allowable from Oct. 11 to Nov. 12 of 26,000 bbl. a day. The minimum demand comes in the winter months, when the allowable reached a low of 10,000 bbl. a day during the month of January. This allowable is divided among the producing wells according to a formula set up by the Conservation Board, based on the rate of flow through a 1-in. orifice, the bottom-hole pressure, the gas-oil ratio and the acreage per well. The spacing is now one well to 40 acres, although in the early development of the crude-oil area some wells were drilled on 20 acres. Products from the processing of Turner Valley crude have not completely captured the Prairie markets. During 1939 considerable volumes of gasoline were imported into Alberta from the United States. Also, in eastern Manitoba, oil products taken by boats up the Great Lakes were marketed in competition with products made from Turner Valley oil. Two things are mainly responsible for this situation; namely,

1. The lower price of Illinois crude oil at the large Imperial Oil refinery at Sarnia, Ontario, in comparison with the price formerly paid for Mid-Continent crude oil, with the resultant lower cost of products and a wider market range.

2. The high cost of transporting oil by rail from Calgary to the distant easterly parts of the Prairies.

There are a number of small refineries or topping plants at various places in the Prairie Provinces but the main refineries using Turner Valley oil are Oil and Gas Products, in Turner Valley; Imperial Oil Company's refinery at Calgary, rebuilt during 1939 at a cost said to be considerably over a million dollars; British American Oil Company's refinery in Calgary, completed this year; British American Oil Company's refinery at Moose Jaw, Saskatchewan; Imperial Oil Company's refinery at Regina, Saskatchewan, and Anglo-Canadian Oil Company's refinery at

TABLE 2.—*Oil and Gas Production in Turner Valley, Province of Alberta, Canada*

Line Number	Field, *County*	Year of Discovery	Area Proved (Drilled), Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1939		At End of 1939		
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
1	Turner Valley, *Alberta*..	1924	3,600	10,000	27,478,850	7,456,000	873,263	15,875	216	34	6		94[1]	104

[b] Footnotes to column heads and explanation of symbols are given on page 239.
[1] Mostly flowing wells.

Brandon, Manitoba. The freight rate on petroleum in tank cars from Calgary is 18½ cents per hundredweight (51.8¢ per barrel) to Moose Jaw, 19¢ per cwt. (53.2¢ per bbl.) to Regina, 35¢ per cwt. (98¢ per bbl.) to Brandon, Manitoba, and 39¢ per cwt. ($1.09 per bbl.) to Winnipeg. There are two 4-in. pipe lines and one 6-in. pipe line connecting Turner Valley to Calgary. The pipe lines are common carriers although owned by the Royalite Oil Co. The rate charged is 9½¢ per barrel. There is a loading charge of 2½¢ per barrel to railway tank cars at Calgary. The development of Turner Valley oil field has reached a stage where only further moderate expansion can take place until new markets are found. Much consideration has been given to the construction of a pipe line, particularly to the head of the Great Lakes at Fort William, Ontario, and the question has arisen as to whether there are adequate reserves in Turner Valley to justify such a project; that is, can sufficient oil be handled to pay the high costs of constructing such a pipe line for the necessary 1250 miles? There is no doubt the problem would be greatly simplified by the discovery of new and large producing fields outside of Turner Valley and a considerable amount of drilling for this purpose has been done in 1939 and will be continued in 1940.

The Turner Valley field has a total length of 17 miles with a large producing area in the south and a smaller one at the north end. In the intermediate area, 8 miles long, one well, the Argus, was completed during the year. It was about 1½ miles from the dry hole of Dalhousie No. 8 well, completed in 1937. The Argus well apparently showed a rather low porosity but has been made to produce a substantial volume by acidizing the limestone. The nearest producer to it, 1½ miles to the southeast, is Advance No. 5A well, which early in the history of the field changed from a naphtha-gas to a crude-oil well but is now classed as a gas well again because of the high gas-oil ratio. Thus, it seems that in

TABLE 2.—(*Continued*)

Line Number	Oil-production Methods at End of 1939		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells		Initial (Gas) Area)	At End of 1939	Gravity A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift								Top Prod. Zone	Bottoms Prod. Wells				
1			2,000+	517[2]	42–43	Rundle (Madison)	Mis	L	Por[3]	6,973	7,441	468	A[4]	Mis	5,870[5]

[2] June 1939.
[3] 120 to 150 ft. thick.
[4] Faulted.
[5] Faulted at depth of 2140 ft. in Mississippian limestone.

spite of low or only moderate porosity the intermediate area between the north and south ends of the field may produce oil but the amount is still somewhat in doubt. Also, the north limits of the north producing area have not yet been found. The structure of the field is believed to be favorable for a further 6 miles northwest of the most northerly producing well but it is unknown whether this whole area is above the oil-water line which in southern Turner Valley is known to be somewhat higher than 4500 ft. and below 4100 ft. below sea level on the top of the Rundle (Madison) limestone, the producing formation. Since the structurally highest gas well drilled in the field has an elevation of 786 ft. above sea level, on top of the same limestone the productive closure of the field is thus now known to be about 4900 ft., of which slightly more than 2000 ft. is closure in the oil zone and the remainder in the gas-naphtha cap.

OTHER FIELDS

Foothills.—In the foothills outside of Turner Valley no successful wells were drilled in 1939. About 22 miles west of Calgary, in the Jumpingpound area, on the east side of the foothills, there is a pronounced fold, which, from the drilling of two previous wells, was known to be underlain by a low-angle fault that cut above the Paleozoic limestone. It was thought, however, that the dip of the fault plane would be steeper than the dip of the strata above it, hence it was believed that the limestone might occur above the fault to the west of the wells already drilled. The drilling of Brown Consolidated No. 1 well to a depth of 6885 ft. did not bear out this assumption, and the underlying fault was encountered at almost precisely the same horizon as in a well a mile to the east on the crest of the anticline. The anticline, therefore, is a drag fold above a major fault and apparently has resulted from a thrust transmitted by a competent mass of limestone still farther west. This information apparently is of very far reaching importance in regard to the interpretation of structures in the foothills and, although the well was abandoned as a failure, the data from it may prove to be extremely valuable in further exploration.

During 1939 three wells were completed in outliers of Paleozoic limestone within the foothills belt and a fourth is still drilling. These were all drilled to test the Devonian limestones underlying the Mississippian beds. In two of the wells, one on Savannah Creek, 25 miles southwest of the south end of Turner Valley, in the Livingstone Range, and one on the Ram River, 110 miles northwest of Calgary, a major fault was encountered under a relatively thin slice of Paleozoic beds and in each case the well passed back into Upper Cretaceous strata under the fault. In the third test, made on Clearwater River 80 miles northwest of Calgary, some oil was encountered in the Devonian between 1100 and

1300 ft. in depth and the whole of the Devonian thickness was drilled without further significant results. It is probable that some more drilling will be done on this structure in 1940. In the other Devonian test, not yet completed on the north end of the Moose Mountain uplift, 40 miles west of Calgary, the well is now at a depth of 6200 ft. apparently in basal Devonian strata without any appreciable shows of oil.

Grease Creek and Brazeau.—Two other areas—Grease Creek, 45 miles northwest of Calgary, and Brazeau, 110 miles still farther northwest—are being tested. Neither well has been completed. Gas under heavy pressure has been encountered in the top of the Blairmore formation in the Brazeau test.

Steveville.—On the plains several wells have been drilled at Steveville, about 100 miles east of Calgary. Substantial shows of oil have occurred in some of these wells but at present the field appears to offer much better prospects of gas apparently over a very wide area. One well now drilling will test the older formations of the Paleozoic, although it is doubtful whether any Silurian and Ordovician rocks are present between strata of Devonian and Cambrian ages.

Near Lethbridge.—Some further drilling has been done south of Lethbridge, Alberta, and a small amount of oil is being produced from two wells in the Del Bonita area. Seismic surveys on the Blood Indian Reserve southwest of Lethbridge point to a structure with considerable south closure on the north-plunging Sweet Grass arch. This structure will be tested in 1940.

Lloydminster.—At Lloydminster, on the Alberta-Saskatchewan boundary, two oil wells have been completed in Alberta and one in Saskatchewan. The oil is heavy and the wells need pumping. The structure is very flat. The area has a number of gas wells, some of which are being used to supply the town of Lloydminster. About 30 miles west of Lloydminster and 6 miles east of Vermilion, a well of heavy gravity oil has been completed on the Battleview structure extending southward to Battle River. Previously a large gas well had been drilled on this structure 16 miles south of the oil well. A well drilled in 1939 about midway between the two gave a large flow of gas. The gas and oil occur at or below the contact between the Upper and Lower Cretaceous beds at depths of 1600 to 1900 ft. This structure appears promising for further developments.

Fort Norman Area.—In the Fort Norman area, on Mackenzie River in the Northwest territories, Imperial Oil Company Limited has two producing oil wells and operates a small refinery. In 1939 a dry hole was drilled. The wells supply oil for fuel and power in mining operations in Great Bear and Great Slave Lake areas and for local use. The refinery, which operates only in the winter, has been increased in 1939 to process 800 bbl. a day in comparison with a former capacity of 300 bbl.

daily. The wells are operated throughout the year and the oil stored in the winter months.

Warwick Field.—In Ontario a number of shallow wells were drilled for petroleum in the Warwick field, Lambton County. These wells are less than 500 ft. deep and production is from Devonian limestones. In some of the wells an initial production of 100 bbl. or more a day was reported but the decline was rapid. This field added a substantial quantity of oil to the production of Ontario in 1939.

Gas.—Some drilling was done in the older gas fields. The main gas developments in Ontario followed the discovery of the Malahide field, Elgin County, by the Union Gas Co. Twenty gas wells and a number of dry holes were completed during the year. The main producing horizon is the top of the Guelph formation, of Silurian age, at a depth of 1050 to 1100 ft. The daily initial flow of gas varied in the wells from less than 1000 M cu. ft. to nearly 2000 M cu. feet.

Gaspe Area.—Following extensive geological work by the Quebec Department of Mines and the favorable recommendations of an area in Gaspe, the Imperial Oil Co. commenced a well late in 1939. Oil seepages were recorded from this area in the Proceedings of the Literary and Historical Society of Quebec in 1836. They were described by Sir William Logan in 1863 but early attempts at drilling ended in failure. Between 1889 and 1901, however, about 50 wells were drilled many of which reached a depth of 2000 to 3000 ft. and a number produced small volumes of oil. A refinery capable of handling 150 bbl. a day was built, but later, owing to the failure of the wells, the whole project was abandoned. The revival of drilling in Gaspe, therefore, by the Imperial Oil Co. is of very considerable interest. The structural conditions are undoubtedly favorable and the problem is one of discovering horizons of adequate porosity to provide reservoir rocks.

Petroleum Developments in Colombia during 1939

By O. C. Wheeler,* Member A.I.M.E.

(New York Meeting, February 1940)

The total oil production from Colombia during 1939 amounted to 23,774,151 bbl., constituting a new high record. Of this amount the Tropical Oil Co. produced 22,374,151 bbl. from its De Mares concession and the Colombian Petroleum Co. produced 1,400,000 bbl. from its Barco concession beyond the eastern Andes. The Socony Vacuum Oil Co. produced a small amount of crude from its Las Monas wells north of the Sogamoso River in the Magdalena Valley for consumption on its own property, but this is not included in the figures given above.

The South American Gulf Oil Co. provided the outstanding development in the country by the completion, late in the year, of its 12-in. pipe line from the Colombian Petroleum Company's Barco concession to the coast at Covenas. This was a notable accomplishment, achieved in the face of tremendous natural obstacles. With the completion of this line there are now two crude-oil outlets from the interior of Colombia to the coast, the other being the Andian National Corporation's line down the Magdalena Valley from Barranca Bermeja. The Barco property becomes the second major producing area in Colombia.

The acquisition of prospective oil lands continued at about the same level as during the previous year. Most of the lands taken up or applied for had their subsurface rights vested in the National Government. Relatively little interest was taken in the leasing of privately owned lands. Tropical surrendered its Putana concession on the Sogamoso River after finding it to be nonproductive. The status of applications for National lands that had been accepted or on which concession contracts had been awarded at the end of the year is shown in Table 3.

In the Magdalena Valley wildcat drilling in the search of new fields was conducted to the east of Puerto Berrio by the Compania de Petroleo Shell de Colombia, Compania Colombiana de Petroleos El Condor and by the Sociedad Nacional del Carare; further down the valley to the east of Puerto Wilches, the Socony Vacuum was drilling two wildcats. No discoveries resulted from this exploratory work. On the Barco conces-

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sion the Colombian Petroleum Co. drilled one wildcat well, which made a small pumper.

The National Government enacted Decree No. 1694 of 1939 on Aug. 28, for the purpose of regulating certain provisions of the Petroleum Law relating to the filing of concession applications, to limitations on acreage holdings and to the surrender of concession contracts.

The Ministry of National Economy, Petroleum Department, issued, under the authorship of Dr. Felix Mendosa and Dr. Benjamin Alvarado, an interesting and highly instructive publication on the petroleum industry in Colombia, entitled La Industria del Petroleo en Colombia (The Petroleum Industry in Colombia). The volume is printed in both Spanish and English. Chapters are included on the history of the petroleum industry in Colombia; a review of the oil industry, including an account of the activities of the operating companies; statistics on production, exports, and refining; geology; and a final chapter on the Colombian Petroleum Laws. An introductory chapter presents a brief summary of items of general interest such as Government, Geography, Climate, Political Subdivisions; Population, and so forth.

Another contribution of interest that appeared during the year was the March issue of *World Petroleum*, which was devoted exclusively to Colombia. This issue was accompanied by a map containing insets showing the well locations in the Infantas and La Cira fields of the Tropical Oil Co., those of the Colombian Petroleum Co. on the Barco property and those on the Socony Vacuum's Restrepo concession.

TABLE 1.—*Oil and Gas Production in Colombia, South America*

Line Number	Field, *Department*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods of 1939	
							During 1939		End of 1939			Number of Wells	
			Oil	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[e]	Producing Gas[e]	Flowing	Artificial Lift
1	Infantas, *Santander*	1918		123,011,003	4,802,464	470	0	0			0		
2	La Cira, *Santander*	1926		127,066,229	17,571,687	600	100	0			0		
3	Las Monas, *Santander*	1926				3	0	0	2	1	0	0	1
4	Petrolea (North Dome) *Santander del Norte*	1933	3,500		1,400,000	68	40	0	12	56	0	56	0
5	Petrolea (South Dome) *Santander del Norte*	1937			0	1	0	0	1	0	0	0	0
6	Rio de Oro, *Santander del Norte*	1937				8	3	0	1	7[1]	0		
7	Carbonera, *Santander del Norte*	1939				1	1	0	0	1[1]	0	0	1
8	Total				23,774,151	1,151	144	0					

[e] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Capable of producing.

OPERATING COMPANIES*

Colombian Petroleum Co.—An outlet for crude oil from the Barco property of the Colombian Petroleum Co. was provided for the first time by the completion in October of the South American Gulf Company's pipe line from Petrolea to Covenas. The property was placed on a steady producing basis beginning the last three and a half months of 1939.

Drilling operations of this company were carried on in the following areas: Petrolea (North Dome); Petrolea, (South Dome); Rio de Oro; Carbonera and Leoncito. Quoting from Mr. Duce:

"1. In the Petrolea field (North Dome), which is a faulted anticline, 40 oil wells were completed during 1939—no dry holes. Of this total, 2 were from the Ostrea beds (shallow) around 475 ft.; 28 were zone I wells, around 700 to 800 ft.; 9 were zone III wells, around 1300 to 1400 ft., and one well was completed in the lower zone IV and top of the Uribante zone, which was a good producer at a total depth of 1284 ft. The gravity of oil in the Petrolea field ranges between 40° and 47° A.P.I. Total production from the field was 1,400,000 bbl. during the last 3½ months of 1939.

"2. There was no activity on the Petrolea (South Dome) during the year 1939. Only one well completed in 1937 at a total depth of 1350 ft. is capable of producing oil.

TABLE 1.—(*Continued*)

Line Number	Repressuring Operations[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
		Gravity A.P.I. at 60° F. Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
								Top Prod. Zone	Bottoms Prod. Wells				
1	31[2]	25.3	0.90	A, B, C zones	Olig Eoc	S	15–22	400–2,200	1,000–2,600	50–200	AF	Cre	4,048
2			0.90	A, B, C zones	Olig Eoc	S	15–25	400–3,950	600–4,294	50–175	AF	Cre	8,051
3				Chuspas	Olig	S					AF	Cre	
4		43.5		Cogollo	Cre	LS					AF	Basal zone IV and top of Uribante	1,284
5		37.7		Zone III	Cre	LS		1,050–1,111			A	CreL	1,350
6		38.0		Catatumbo	Eoc	S			1,300–1,400		AF	Catatumbo	1,608
7		21.5		Barco				1,981	1,991	10	-	Barco	2,722
8													

[2] Number of repressuring key wells.

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* Data regarding company operations provided as follows: Colombian Petroleum Co., James Terry Duce; Socony Vacuum Oil Co., J. C. Case and C. S. Corbett; Compania de Petroleo Shell de Colombia and Compania Colombiana de Petroleos El Condor, H. Wilkinson.

"3. At Rio de Oro, three oil wells were completed during 1939 from the Catatumbo formation, one of which was deepening at the close of the year. Gravity of oil, 38°. Structure is a narrow, tight anticline, considerably faulted. Area of field is still undefined.

"4. At Carbonera one oil well was completed in 1939 and a second well was drilling. This was a wildcat well.

"5. Leoncito No. 1—a wildcat completed in 1938 as a dry hole, total depth 3045 ft. No additional work done in 1939 in this area.

"*Refinery.*—During the year 1939, a refinery with a capacity of 500 bbl. daily was constructed at Petrolea.

"*Pipe Line.*—The South American Gulf Oil Co. completed its pipe line from Petrolea field to the Covenas terminal, a maritime port at Bahia Cispata of the Gulf of Morrosquillo of the Caribbean Sea, in the Department of Bolivar about 240 miles east of Cristobal, Panama. Data follow:

"Length of line, 263 miles.

"Type, 12-in. welded steel pipe throughout, except a 5-mile section from the 5286 ft. level at Paso Rieber, the highest point crossed, to a point 2800 ft. lower.

"Capacity. Present facilities 25,000 bbl. per day. Potential capacity of line, 70,000 bbl. per day.

"Pump Stations. Petrolea, elevation 217 ft. above sea level. Tarra, elevation 2378 ft. above sea level. Convencion, elevation 3182 ft. above sea level.

"Tankage. At Petrolea, two 80,000-bbl. tanks; three 55,000-bbl. tanks. At Covenas, six 118,000-bbl. tanks. First oil to be loaded into tankers at Covenas was on Oct. 21, 1939."

TABLE 2.—*Summary of Drilling Operations in Colombia in* 1939

Important Wildcats Drilled in 1939

	Department	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Survey	Lat.	Long.			
1	Santander	Narino No. 1	Restrepo Conc.		6,515	Puerto Santos	Chuspas
2	Santander	Zambito No. 1	6°16′49″ N.	0°25′24″ W. of Bogotá	2,388	Mesa	
3	Santander del Norte	Carbonera No. 1	8°25′ N.	1°34′ E. of Bogotá	2,772	Mirador	Barco

Socony Vacuum Oil Co.—The Socony Vacuum conducted wildcat drilling in two localities north of the Sogamoso River during 1939. Its Narino No. I well, 25 km. east of Puerto Wilches on the Restrepo concession, was abandoned in January because of mechanical difficulties, at a depth of 6516 ft. in the Chuspas formation of the Oligocene. A second well, called Narino No. 3, was started near by and had reached a depth of 7644 ft. at the end of the year. About 10 km. to the northeast on this same concession, the company was drilling on a geophysical prospect, a well designated as Peralonza No. 1. This well had reached a depth of 9274 ft. at the end of the year, where it was fishing. No drilling operations were carried on on the Las Monas structure. A small amount of oil was produced from that structure for fuel purposes.

Compania de Petroleo Shell de Colombia commenced and was drilling at the end of the year a well known as Monte Oscuro No. 1 on its concession southeast of Puerto Berrio. Coordinates of this well are: latitude 6°9′58″ N., longitude 0°13′59″ W. of Bogota. This well starts drilling in the La Cira formation.

Compania Colombiana de Petroleos El Condor carried on drilling activities on two wells, known as Zambito No. 1 and Baul No. 1, both of which are on the concession southeast of Puerto Berrio, which was acquired from Concorcio Minera Nacional. The Zambito well has the following coordinates: latitude 6°16′49″ N.; longitude 0°25′24″ W. of Bogota. It was started drilling in the Mesa formation and was finished as a water well at a depth of 728 meters. Baul No. 1 is on the same concession at latitude 6°14′33″ N.; longitude 0°18′46″ W. of Bogota. This well also started drilling in the Mesa formation. It was reported testing at the end of the year.

Sociedad Nacional del Carare.—The Sociedad Nacional del Carare holds a National concession about 35 km. southeast of Puerto Berrio,

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Drilled by	Initial Production per Day	Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.	Remarks
		Oil, U. S. Bbl.		Casing	
1	Socony-Vacuum Oil Co.	0			Abandoned because of mechanical difficulties Jan. 28, 1939.
2	Cia. Colombiana de Petroleos El Condor	0			Water well.
3	Cia. Colombiana de Petroleo	46	2½-in. tubing	275	Plugged back to 1999 ft.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939		5
Number of oil wells completed during 1939	143	1
Number of gas wells completed during 1939	0	0
Number of dry holes completed during 1939	0	2

where a test well, San Fernando No. 2, was drilled during the year to a depth of 9272 ft. Drilling of this well was started in the Real formation of the Miocene. The well was being tested in the Eocene and Oligocene sands at the end of the year. The tests were negative and the well was scheduled for abandonment.

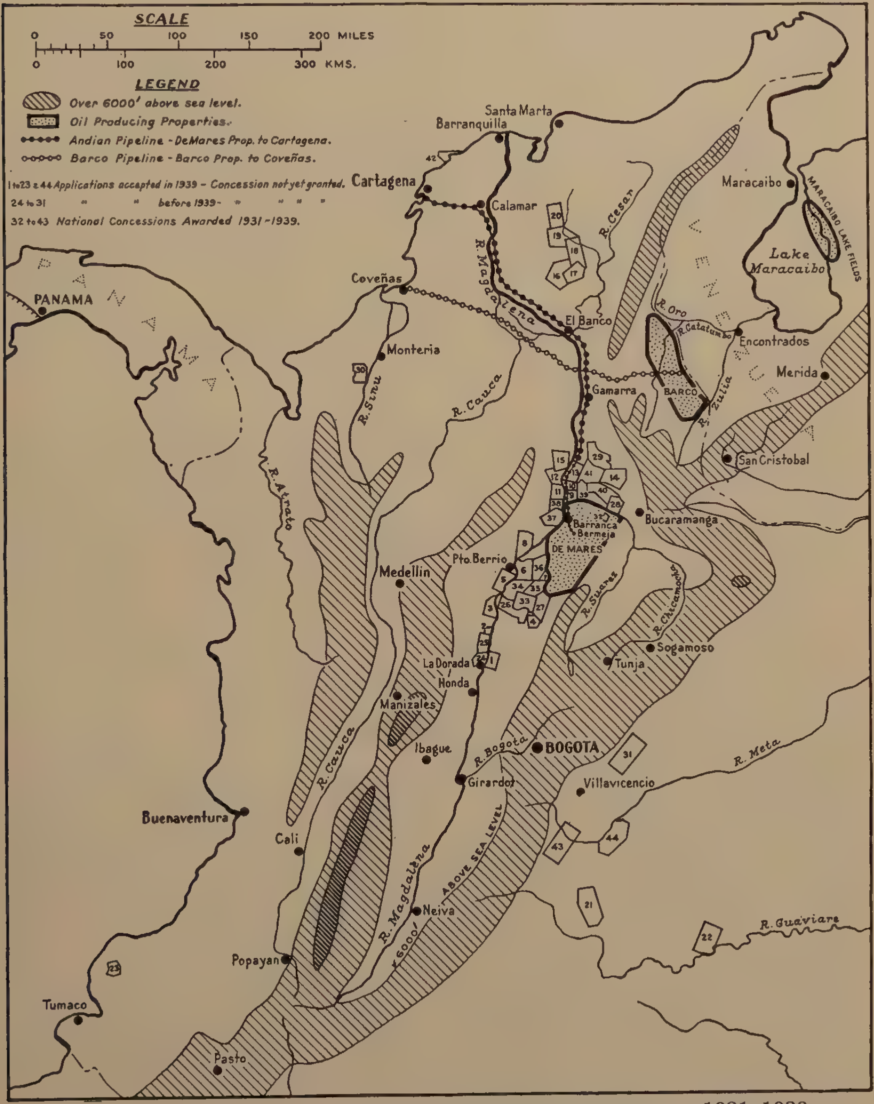

FIG. 1.—APPLICATIONS FOR CONCESSIONS ON NATIONAL LANDS, 1931–1939.

Tropical Oil Co.—The Tropical completed 100 new wells on its De Mares concession during the year. These are C-zone completions but

TABLE 3.—*Status of Applications*

No. on Fig. 1	Company	District	Final Date	Area, Hectares
	APPLICATIONS ACCEPTED IN 1939 BUT CONCESSIONS NOT YET GRANTED			
			Date Accepted	
1	Pedro Londono Saenz	Rio Negro	Dec. 15	49,959
2	Manuel Toro	Rio La Miel	Aug. 22	5,091
3	Giovanni Serventi	Rio Nare	Dec. 13	49,431
4	Francisco Laserno	Rio Minero	July 7	18,354
5	William Neilson	Puerto Berrio	Aug. 17	45,006
6	Carlos Botero Mejia	Puerto Berrio	May 9	39,537
7	Francisco Rocha Vargas	Rio Carare	Jan. 16	3,383
8	Martin Theves	Rio Ite	Dec. 13	49,580
9	Carlos Arturo Torres Pinzon	Rio Sogamoso	May 11	12,609
10	Hernando Salazar	Puerto Wilches	Sept. 21	9,304
11	Compania de Petroleos del Valle del Magdalena	Rio Cimitarra	March 30	32,880
12	Luis Alberto Villamizar	Rio Simiti	Aug. 8	22,995
13	William A. MacCarthy	Rio Paturia	March 9	20,520
14	Hernando Franco	Rio Lebrija	July 25	48,970
15	Salvador Camacho Roldon	Rio Simiti	June 22	49,468
16	Compania Petrolera de Bogota	Rio Cesar	Dec. 7	47,853
17	Rene Granger	Rio Cesar	July 6	18,514
18	Compania Anglo-Colombiana de Petroleos	Rio Ariguani	Aug. 21	47,784
19	Compania de Petroleo La Estrella de Colombia	Rio Ariguani	Dec. 6	48,568
20	Compania de Petroleo La Perla de Colombia	Rio Ariguani	Aug. 22	49,985
21	Compania Anglo-Colombiana de Petroleos	Rio Ariari	Nov. 22	99,319
22	Richmond Petroleum Co	Rio Guayabero	Aug. 18	100,000
23	Antonio Jose Castro Borrero	Rio Patia	Nov. 25	16,540
44	Antonio Borda Carrizoba	Rio Metica	Nov. 15	99,938
	NATIONAL CONCESSIONS AWARDED 1931–1939			
	Contracts terminated and areas returned to the Nation:		Date Surrendered	
32	Tropical Oil Co	Rio Sogamoso (Putana)	Oct. 17, 1939	7,430
	Contracts effective as of Dec. 31, 1939:		Date Awarded	
33	Bernardo Mora Concession (transferred to Compania de Petroleo Shell de Colombia, Oct. 27, 1937)	Rio Ermitano	Sept. 28, 1937	50,000
34	Consorcia Minero Nacional Concession (transferred to Compania Colombiana de Petroleos El Condor, Mar. 3, 1938)	Rio Ermitano	Feb. 22, 1938	44,258

TABLE 3.—(*Continued*)

No. on Fig. 1	Company	District	Final Date	Area, Hectares
35	Sociedad Nacional del Carare (under joint exploration with Tropical Oil Co.)	Rio Carare	Sept. 22, 1936	34,783
36	Compania de Petroleo Shell de Colombia	Rio Carare	March 2, 1938	49,906
37	Compania Colombiana de Petroleos El Condor	Rio Cimitarra	Sept. 15, 1938	47,810
38	Juan de Dios Gutierrez	Rio Cimitarra	May 23, 1939	16,927
39	Socony-Vacuum Oil Co. of Colombia	Rio Sogamoso	Aug. 30, 1939	27,040
40	Luciano Restrepo Concession (transferred to Socony-Vacuum Oil Co. of Colombia, Feb. 22, 1935)	Rio Sogamoso	Sept. 19, 1934	49,232
41	Compania de Petroleos del Carare	Rio Lebrija	March 3, 1938	49,636
42	Daniel A. del Rio Concession (transferred to Compania Petroleo de Bogotá, June 2, 1939)	Barranquilla	May 25, 1938	20,141
43	Compania de Petroleo Shell de Colombia	Rio Ariari	Aug. 10, 1939	99,975
44	See above.			
	APPLICATIONS ACCEPTED BEFORE 1939 BUT CONCESSIONS NOT YET GRANTED			
24	Carlos de Narvaez	La Dorada	Dec. 5, 1938	36,015
25	Jaime Gutierrez	Buenavista	Dec. 5, 1938	49,199
26	Evaristo Obregon	Rio Ermitano	July 5, 1937	42,546
27	Mora & Palaez Hnos	Rio Minera	March 16, 1938	42,336
28	Frederick R. Ryan	Rio Sogamoso	June 22, 1938	19,328
29	Sindicate de Inversiones, S. A.	Rio Lebrija	June 4, 1937	45,905
30	Roberto Pena	Rio Sinu	Oct. 5, 1938	44,954
31	Texas Petroleum Co.	Rio Upia	Dec. 1, 1938	100,000

six of them are also perforated in the B zone and are termed B-C producers. All the wells were located on the La Cira structure and all were producers. Their average initial production was 528 bbl. Production from the Infantas and La Cira fields totaled 22,374,151 bbl., of which 287,505 bbl. was petroleum condensate added to crude.

Petroleum Development in Cuba during 1939

BY ROBERT H. PALMER*

(New York Meeting, February 1940)

Bacuranao Field.[1]—Bacuranao field is about 12 miles east of Havana, along the contact between Cretaceous sediments and a serpentine intrusion. The zone lies within an extensive anticlinorium. The field had no developments during the year 1939. The production of 9½ bbl. per day is distilled and the gasoline and kerosene are extracted. The asphalt residue is sold for road construction. The gas is compressed and

TABLE 1.—*Oil and Gas Production in Cuba*

Line Number	Field, *Province*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1939		End of 1939		
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[e]	Producing Gas[c]
1	Bacuranao, *Habana*............	1915	55	0	155,000	3,487	*x*	1.8	62	0	0	*x*	10	*x*
2	Motembo,[1] *Santa Clara*........	[4]	85	0	296,259[1]	104,050[1]	*x*[2]	*x*[2]	313	133	*x*	*x*	142[1]	*x*

[b] Footnotes to column heads and explanation of symbols are given on page 239.
[1] Production of Motembo Field is gasoline only.
[2] No estimate. Gas used in shops and lighting.
[4] Known since about 1880.

Line Number	Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells											Depth, Avg. Ft.				
	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Gravity A.P.I. at 60° F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	0	10	*x*	*x*	[5]	*x*	Habana	CreU	SH, P	*x*	400	1,200	*x*	MI	CreU	2,300
2	0	142	*x*[3]	*x*	[6]	0.028	Not named	UEoc?	P	*x*	800	1,200	*x*	[7]	*x*	2,400

[3] Wells vary from 0 to 133 lb. per sq. in.
[5] Vary from 29 to 33.
[6] Vary from 59 to 61.
[7] Occurs in massive serpentine.

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* Geologist, Cia. Petrolera Taina S. A.

[1] Data furnished by Jose Gonzalez of Union Oil Co.

sold in cylinders. Gas pressure in the various wells is varied. For the most part the pressure is low. One well had an estimated initial pressure of 2000 lb. per sq. in. but it lasted only a short time. One well flowed for six months.

Motembo Field.[2]—Motembo field is in the northwest corner of the Province of Santa Clara and is 105 miles east of Havana. Production comes from three areas, about 1½ miles apart along a northwest-southeast line, on a large serpentine mass. The product occurs in fracture zones within the serpentine at depths of from 800 to 1200 ft. It is a colorless gasoline from 59 to 61 and in one case 68 Baumé, and is readily marketed without processing. To the end of the past year, 296,259 bbl. had been marketed at a price of from $8.20 to $10.50 per barrel. The deepest well drilled, 2400 ft., encountered only serpentine.

Four of the wells have flowed, but most of them are pumped. Gas pressure is for the most part low, though pressures of 133 and 160 are known. There is sufficient gas to provide fuel for power, including lighting, pumping and the shops.

Profits for the most part have come from flush production. Initial production has amounted to as much as 1500 bbl. per month. This continues for one to four months or more, then declines to a few barrels, therefore continuous drilling is necessary.

TABLE 2.—*Summary of Drilling Operations in Cuba*

Important Wildcats Drilled in 1939

	Province	Location		Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
		Lat.	Long.					
1	Santa Clara....	22°28′ N.	79°36′ W.	4,034	Cretaceous	Cretaceous	Atlantic Refining Co.	Dry
2	Matanzas......	22°45′ N.	80°52′ W.	6,020	Oligocene	Cretaceous	Atlantic Refining Co.	Dry
3	Habana........	22°54′ N.	82°32′ W.	5,270	Oligo-Miocene	Cretaceous	Shell	Dry
4	Habana........	900 m.s. of 5270′ well		10,035	Oligo-Miocene	Cretaceous	Shell	Dry
5	Habana........	23°11′ N.	82°11′ W.	1,852	Miocene	Cretaceous	Lloyd Brown	Drilling, oil shows
6	Pinar del Rio...	22°52′ N.	82°52′ W.	2,034	Cretaceous	Cretaceous	Carlos Cusachs	Drilling, oil and gas shows

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	0	2
Number of oil wells completed during 1939	0	4
Number of gas wells completed during 1939	0	0
Number of dry holes completed during 1939	0	4

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[2] Production data to end of 1935 furnished by Motembo Mining Co. and St. John Naphtha Co.; 1936 Production, Boletin de Minas No. 17; 1937–1939 Production and well data furnished by Ing. Ricardo E. Castillo.

Petroleum and Gas in Ecuador

By E. Escobar Pallares,* Member A.I.M.E.

TABLE 1.—*Oil and Gas Production in Ecuador*

Line Number	Field, Santa Elena County, Province of Guayas	Age, Years	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	During 1939		End of 1939		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
1	Ancon { H.C.T.[1]	19	*y*	0	*y*	1,8*xx*,*xxx*	20,*xxx*	*y*	188	6	2	14	172	0
	Ancon { L.C.T.	19	*y*	0	*y*	3*xx*,*xxx*	*y*	*y*	361	17	50	0	311	0
			12,000		20,703,189	2,173,555	20,*xxx*	2,267	549	23	52	14	483	0
2	Cautivo-Achallan	17	2,*xxx*	0	494,694	62,552	*xxx*	*x*	172	14	96	0	76	0
3	Carolina and Santa Paula[2]	*y*	2,000	0	534,529[2]	36,017	0	0	55	6	43	0	12	0
4	Concepcion	9	*y*	0	83,762	15,397	0	0	12	6	1	2	9	0
5	El Tambo	8	*x*	0	8,760	1,222	0	0	6	0	0	0	6	0
6	Mina Tigre	2	*y*	0	65,622	65,622	0	0	7	1	4	0	3	0
	Total				21,890,556	2,354,365	20,*xxx*	2,267	801	50	196	16	589	0

Line Number	Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
	Number of Wells										Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Gravity A.P.I. at 60° F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	35	137	*y*	1,050	40	0	Atlanta	Eoc	S	Fis	3,500	6,000	2,500	AF	San José sandstone	8,053
	0	311	*y*	*xxx*	36	*y*	Socorro	Eoc	S	Por	1,200	1,800	600	*y*		
	35	448														
2	1	75	200	200	29	*y*	Socorro(?)	Eoc	S	Fis	700	1,200	300	*y*	Socorro(?)	1,295
3	3	9	145	145	29	*y*	Socorro(?)	Eoc	S	Fis	632	836	200	*y*	Socorro(?)	1,506
4	2	7	*y*	*y*	38	*y*	Atlanta	Eoc	S	Fis	*y*	*y*	*y*	*y*	Atlanta	3,570
5	0	6	*x*	*x*	34	*y*	Socorro	Eoc	S	Por	9*xx*	1,*xxx*	*y*	*y*	Socorro	1,300
6	2	1	800	800	39	*y*	Atlanta	Eoc	S	Fis	2,980	3,993	*y*	AF	Atlanta	3,993
	43	546														

[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] H.C.T. means the deep zone for High Cold Test crude oil. L.C.T. means the shallow zone for Low Cold Test crude oil. They occur in the same area.

[2] In the same area there are many shallow pits and some wells. In the column showing total oil production to the end of 1939 are included 355,997 bbl. from shallow pits before 1939. During the last year there was no production from shallow pits.

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Petroleum in India and Burma in 1938

(New York Meeting, February 1940)

THE separate outputs of Burma and India in 1937 were 274,664,365 gal. valued at £4,474,147 and 75,657,857 gal. valued at £1,030,591, respectively. The corresponding figures for the year 1938 were 263,823,265 gal. valued at £3,766,810 and 87,082,371 gal. valued at £1,234,563, respectively, which is a slight increase in total quantities but a fall in value for the combined outputs of Burma and India. The appreciable increase from India in 1938 is due to an increase of over 11 million gallons from Attock and a little from Digboi, while the decrease from Burma is due to a fall of nearly 9 million gallons from Yenangyaung, over 3 million gallons from Yenangyat (and Lanywa) and half a million gallons from Minbu (Table 1).

TABLE 1.—*Quantity and Value of Petroleum Produced in India and Burma*

Fields	Year 1937		Year 1938		January to September 1939
	Quantity, Gal.	Value, Pounds	Quantity, Gal.	Value, Pounds	Quantity, Gal.
India:					
Assam—Digboi	65,718,437	£ 843,760	65,968,951	£ 840,656	35,392,561
Punjab—Attock	9,939,420	186,831	21,113,420	393,907	22,759,840
Total	75,657,857	1,030,591	87,082,371	1,234,563	58,152,401
Burma:					
Kyaukpyu	12,437	4,474,147[a]	11,189	3,766,810	199,523,036
Minbu	3,418,311		2,929,940		
Singu	119,858,608		120,769,811		
Thayetmyo	2,001,180		2,712,800		
Upper Chindwin	2,502,140		2,359,568		
Yenangyat (including Lanywat)	25,067,655		22,022,443		
Yenangyaung	121,804,034		113,017,514		
Total	274,664,365	4,474,147	263,823,265	3,766,810	199,523,036

[a] Estimated.

The amount of gasoline produced from natural gas during the year 1938 was 10,587,291 gal. in Burma and 496,163 gal. in the Punjab.

Material taken from the Review of the Mineral Industry of India and Burma during 1938, by permission of the Director of the Geological Survey of India. (Few figures for the year 1939 are yet available.) Manuscript received at the office of the Institute Feb. 14, 1940.

BURMA

The total production in Burma during 1938 was less than in the previous year, but the resources of the field as a whole are sufficient to ensure an adequate supply of oil for many years. At the end of 1938 there were 2905 wells producing in the field. Besides a large number of wells drilled to shallow sands, this total includes 195 hand-dug wells, whose continued existence is one of the interesting features of the field.

No important discoveries of new producing horizons were made during the year. Satisfactory results continue to be obtained from gas drives in the leased blocks; in addition to gas drives, gas is also injected with the object of repressuring and storage. Casing policies continue to be carefully designed to protect the oil sands against the danger of flooding by water and, in general, production methods throughout the field are characterized by a realization of the importance of the conservation of oil and gas and the prevention of waste, whether simple or underground.

Singu.—In 1938 the increase in the output from the Singu field was continued. This increased production was due not only to the rapid development of the valuable area in the southern part of the field but also to the successful results obtained from the first wells to produce from behind the practically completed river training wall of the Burmah Oil Co. At the end of the year 562 wells were producing, as compared with 568 in December 1937. In addition, a number of wells remained cemented above productive sands. These wells can be drilled into productive sands in a very short time and the total field production substantially increased.

No radical change has been made in production methods. The fundamental principle underlying the policy of the major operating company at Singu is to make adjustments at each well to attain a maximum oil recovery with a minimum production of gas. Wells with high gas-oil ratios are shut in, and the casinghead gas remaining after the satisfaction of the field requirements is returned to dry gas sands for storage, or to certain areas for repressuring purposes. The repressuring operations of the British Burmah Petroleum Co., Ltd., continued to give satisfactory results. The dry gas produced from the new gasoline-extraction plant is used either in connection with these schemes or as fuel.

Continuous gas lift on some wells producing from lower division sands and gas-displacement pumping on wells producing from upper division sands were continued on a small scale, but production from the great majority of the wells in the field was obtained by ordinary pumping methods.

Yenangyat.—Although, during 1938, active development continued at Yenangyat, the results obtained were somewhat disappointing and a decline in the total production from the Pakokku district, excluding

Lanywa, was reported. Production from the Lanywa field during 1938 was about the same as in 1937. The successful application of directional drilling methods in order to tap the known oil sands beneath the Irrawaddy River has greatly improved the prospects of the Lanywa field. Back pressures are maintained on nearly all the wells in this model field, which is operated by the Indo-Burma Petroleum Co., Ltd. While a number of wells are pumped from a central power, the majority have individual pumping motors. The gasoline plant was operated throughout the year and gave a satisfactory yield.

Minbu.—In the Minbu district, 318 wells were producing at the close of the year, but apart from routine operations there had been little activity in the district.

There was a slight decrease during 1938 in the total production from the Indaw field. All producing wells except four at the northern end of the field were successfully operated by the automatic gas-lift system.

Thayetmyo.—In the Thayetmyo district, while production decreased slightly in the Padaukpin field, that of the Yenanma field showed a further considerable increase. An extension of the known producing area was proved in this field. The supply of natural gas from the Pyaye field for use as fuel in the Burma Cement Company's factory was maintained during 1938.

Kyaukpyu.—The output from Kyaukpyu remained at its usual low level.

INDIA

Assam.—In Assam output of the Digboi field increased slightly. Shallow drilling has been done in the Kharjam mining lease to investigate the structure in the wide area where the rocks are hidden beneath the alluvium, and drilling to test the prospects of obtaining oil in the Namdang mining lease is in progress. Preparations are advanced for borings to obtain geological information from beneath the alluvium gravels in the Namphuk prospecting license area.

Geophysical and geological work has been done in the area covered by the Tiru Hills prospecting license, and information boring will be necessary before the prospects of finding oil at depth can be evaluated. Geophysical surveying, both gravity and seismic methods, has been carried out over a large portion of the Assam Valley, in an attempt to discover whether any structure suitable for the concentration and retention of oil occurs hidden below the blanket of alluvium that occupies this valley. This work was still in progress at the end of the year.

In the Surma Valley there was no production. The seismic work at Masimpur gave no help in elucidating the structural complications, and core drilling was started to obtain geological information from considerable depth. One of the core holes has since reached objective at

5000 ft. A further large program of shallow information boring to trace the rock boundaries obscured by alluvium, and thus further to elucidate the details of the structure, was initiated during the year and is in progress.

Geological mapping was done in the Olahtaung concession on the Arakan Coast, and in the area covered by the Sylhet prospecting license; and an air survey of Tripura State has been made preparatory to detailed geological work on the ground.

TABLE 2.—*Imports of Kerosene Oil into India*

From	Year 1937		Year 1938	
	Quantity, Gal.	Value, Pounds	Quantity, Gal.	Value, Pounds
U. S. S. R.	27,377,419	£ 686,405	3,629,596	£ 87,467
Iran	8,218,665	227,595	26,507,700	680,955
Burma	93,466,680	2,840,037	126,671,677	3,560,009
Sumatra	27,955,437	647,049	8,264,220	242,802
Borneo (Dutch)			10,892,243	283,000
U. S. A.	3,011,333	48,904	1,006,940	21,387
Other countries	2,815,014	66,712	11,472,364	282,156
Total	162,844,548	4,516,702	188,444,740	5,157,776

TABLE 3.—*Imports of Fuel Oil into India*

From	Year 1937		Year 1938	
	Quantity, Gal.	Value, Pounds	Quantity, Gal.	Value, Pounds
U. S. S. R.			2,381,494	40,348
Iran	97,611,519	963,679	98,724,439	910,726
Burma[a]	1,099,122	23,490	2,439,328	58,469
Straits Settlements	10,108,149	117,851	1,749,983	23,338
Borneo (British)	13,050,640	200,593	13,445,351	188,798
Borneo (Netherlands)	5,426,441	73,762	12,382,155	174,328
Other countries	513,185	8,440	4,094,020	53,277
Total	127,809,056	1,387,815	135,216,770	1,449,284

[a] From April 1, 1937.

In the Sitakund concession preparations had been completed to undertake an extensive program of shallow drilling to obtain geological information regarding the structure of the western flank, and at the end of the year drilling was about to start.

The Punjab.—In the Punjab the Attock Oil Co. Ltd. operated the Khaur and Dhulian fields and also made tests at Ganda Kas and Jhatia out fields.

In the Khaur field the deep test referred to in last year's report was a disappointment—producing ⅘ bbl. only of oil daily along with a considerable quantity of water. This, it appears, will continue for some time to come.

No further drilling was undertaken at this field and production was restricted by producing only from wells where conditions are unsuitable for closing down.

In the Dhulian field developments have continued to be satisfactory. The two wells reported as producing 480 and 640 bbl. of oil per day, respectively, were mudded off pending the erection of the new refinery. Two more wells were drilled into the 7500 to 7700-ft. horizon and gave initial production of 2200 and 3000 bbl. daily, respectively. Both these wells were beaned down to an aggregate of about 1700 bbl. daily, partly to suit refinery requirements and storage facilities and partly in the interests of economical recovery of production. Three other wells were drilled and cemented above the main oil horizon, and another development well has been stopped temporarily at 6470 feet.

TABLE 4.—*Exports of Paraffin Wax from India*

To	Year 1937		Year 1938	
	Quantity, Tons	Value, Pounds	Quantity, Tons	Value, Pounds
United Kingdom	9,422	£315,840	3,994	£142,563
Germany			887	23,160
Netherlands	994	31,451	155	5,668
Belgium	974	30,870	240	8,776
Italy	860	27,166		
China	2,111	52,333	800	20,896
Union of South Africa	1,903	54,858	695	18,153
Portuguese East Africa	2,085	60,493	2,098	54,784
Canada	835	26,368		
U. S. A.	755	24,105	25	914
Mexico	2,409	89,066	400	14,627
Colombia	1,254	39,588		
Chile	650	20,526		
Australia	127	4,011		
Other countries	1,294	43,036	14	358
Total	25,673	819,711	9,308	289,899

At Ganda Kas, about 30 miles northwest of Khaur, a test well was carried down to 1775 ft. but was abandoned because of structural complications. Drilling operations on a second test well are in progress.

A test well at Jhatla, about 30 miles south of Khaur, was drilled and carried down to 3758 ft. at the end of the year. It is being deepened and may be taken down to 7000 ft. or deeper.

Petroleum and Gas in Iran during 1939

(New York Meeting, February 1940)

Masjid-i-Sulaiman.—There have been no new developments in the Masjid-i-Sulaiman field during the year. Drilling, deepening and acidizing operations for maintenance of production have continued normally. Reservoir conditions have been unchanged, the rate of fall of dome pressure remaining very low—at about 0.4 lb. per sq. in. per million tons net production. Drilling on the Lali structure northwest of Masjid-i-Sulaiman has continued but oil has not been encountered in commercial quantities.

Haft Kel.—The progressive drilling program extending the production capacity of the Haft Kel field was completed early in the year and the field is now on a routine maintenance basis. Drilling has continued on the white-oil springs structure northwest of Haft Kel.

TABLE 1.—*Production of Crude Oil in Iran in* 1939
TO NEAREST 10,000 BARRELS

Masjid-i-Sulaiman[a]		Haft Kel		Total	
Tons	Barrels	Tons	Barrels	Tons	Barrels
3,463,587	26,670,000	6,626,193	50,360,000	10,089,780	77,030,000

[a] Net production; i.e., excluding products recycled to reservoir.

Naft-i-Shah.—No developments of interest have occurred in Naft-i-Shah field. Offtake is for local markets only. A further large producer was completed during the year.

Gach Saran.—By the end of 1939, work on plant and pipe lines to put the field on a production basis was approaching completion. Two substantial producers were also drilled in the initial production area.

Pazanun and Agha Jari.—No further drilling was carried out on the Pazanun structure during the year, gas only having been obtained to depths exceeding 8000 ft. On the adjacent Agha Jari structure, however, a second satisfactory oil producer was completed.

Received through the courtesy of the Anglo-Iranian Oil Co., Ltd., London, England. Summarized at meeting; manuscript received at the office of the Institute March 13, 1940.

Petroleum Development in Mexico during 1939

By T. R. Armstrong*

(New York Meeting, February 1940)

During the year 1939, Mexican production totaled 42,479,000 bbl.; a daily average of 116,381 bbl. or a little over 2 per cent of the estimated world production. The Mexican Government operates 100 per cent of the refining branch of the industry, 100 per cent of the domestic distribution, 96 per cent of the crude production and 92 per cent of the total exports.

No discussion of the Mexican petroleum industry in 1939 is adequate without reference to the "expropriation" of the foreign-owned oil properties in Mexico by executive fiat on March 18, 1938.

The forcible seizing of the properties culminated a long series of efforts on the part of the Mexican Government to obtain control of the oil properties developed through foreign initiative and with foreign capital in Mexico.

The heart of the issue is whether the Mexican nation or any nation may with impunity confiscate the legally acquired properties of American citizens. The Department of State of our Government has in its communications to Mexico emphasized the fact that its "expropriation" of American properties was confiscatory because Mexico had failed to make "adequate, effective and prompt compensation"; that the taking was no less confiscatory "because there may be an expressed intent to pay at some time in the future," and that, consequently, "Mexico has assumed and continues to assume to exercise a right without compliance with the condition necessary to give such exercise a recognizable status of legality."

Mexico has professed its willingness to pay for the oil properties but at the same time through its Supreme Court it has declared that the owners or lessees do not have the exclusive right to extract and dispose of the oil in the subsoil. This is a reversal of the Mexican position with respect to oil as set forth in the Mexican mining laws, affirmed by Mexican Supreme Court decisions, and as clarified in the Warren-Payne and the Morrow-Calles agreements, as well as in diplomatic correspondence.

Efforts to Settle the Controversy

Responding to suggestions from the State Department, representatives of the principal oil companies undertook in 1939 to effect a direct

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* Standard Oil Co. (N. J.), New York, N. Y.

settlement of the controversy through private negotiations with the Mexican Government. In their efforts to find a solution to the problems created by Mexico's forcible seizure of their properties, the managers of the foreign-owned oil companies on Jan. 26, 1939, suggested to the State Department as a basis for settlement that if the properties were returned they would be willing to work out with Mexico a long-term contract by which the interests of the workers, of the Mexican Government, and of the companies' stockholders would be protected, and at the end of the term the properties would be turned over to the Mexican Government free and clear of all claims of the companies. The companies' representative and President Cardenas considered the proposals in several conferences, which unfortunately proved fruitless.

The companies had made plain both prior to and after the private negotiations that they were willing to submit the issues of the legality of the expropriation decree and the validity of the seizures to an impartial Arbitration Board.

As a result of the breakdown of direct negotiations and following a decision of the Mexican Supreme Court of Dec. 2, 1939, which closed all further opportunities for a fair settlement at the hands of the Mexican Government, the companies found themselves at the end of 1939 relying on the State Department for assistance in bringing about an equitable settlement.

The American companies contend that the decision of the Mexican Supreme Court, which arbitrarily deprives the companies of the major portion of the value of their properties, constitutes a denial of justice which warrants diplomatic interposition. Under the circumstances, the State Department alone is in a position to insure a fair settlement of the dispute.

PRODUCTION UNDER MEXICAN CONTROL

As previously stated, Mexican production for the year 1939 is estimated at 42,479,000 bbl. This was divided by areas as shown in Table 1. Of the 1146 producing wells in Mexico 659 are in the Northern district, 262 in the Southern, 25 in Poza Rica and 200 in the Isthmus. Poza Rica, with 2 per cent of the producing wells, produced 61 per cent of the total production; Northern district, with 57 per cent of the wells, produced 13 per cent of the production; Southern district, with 23 per cent of the wells, produced 11 per cent; Isthmus area, with 18 per cent of the wells, produced 15 per cent of the production.

That the Mexican Government has found more difficulties than it expected in operating the seized oil properties is apparent from the contents of a memorandum by the General Director of the Mexican Government Oil Co., prepared after 15 months of government operation of the foreign-owned oil properties, in which he showed that the number of workers in the petroleum industry at the time of the seizure was 15,895 and a year later had jumped to 19,316, and the monthly disbursements had increased from Pesos 4,273,217 to Pesos 6,500,000. He also brought out the fact that it had been impossible to carry into effect completely the decision of the Federal Labor Board of Dec. 18, 1937—which decision the oil companies had opposed on the ground that it was impossible to comply with its terms.

TABLE 1.—*Mexican Oil Production by Areas*
BARRELS

Field	Year			Total to End of 1939
	1937	1938	1939	
Northern (11°–14°A.P.I.)	9,806,000	5,344,000	5,508,000	746,013,000
Southern (20°–24°A.P.I.)	8,292,000	4,230,000	4,652,000	1,024,000,000
Poza Rica (30°–32°A.P.I.)	18,634,000	22,021,000	26,072,000	95,831,000
Isthmus (23°–33°A.P.I.)	9,958,000	6,684,000	6,247,000	105,649,000
Total	46,690,000	38,279,000	42,479,000	1,971,493,000
Daily average	127,919	104,875	116,381	

A further indication of the unsatisfactory progress of the oil industry under government management is to be found in the address of President Cardenas to the representatives of the Petroleum Workers Syndicate calling for a reduction of 5000 employees and for lowering of the salaries of the higher paid employees. The President also indicated that it would be necessary to withdraw some of the benefits and allowances in the form of housing or the equivalent for housing rent which the oil companies had formerly given. The President also pointed out that the labor unions' demands for the unionization of higher employees was not practical.

These points are pertinent primarily because they tend to bear out the contention of the oil companies that the original demands of the Mexican Government prior to the seizure of the properties were not only unreasonable, but could not be carried out without serious damage to the industry.

Daily average crude production was gradually increased from 90,400 bbl. per day in January to 147,000 bbl. per day in September and October but had to be reduced to 118,000 in November and to an estimated 95,000 in December, owing to storage congestion. These figures may be compared with production prior to March 18, 1938, of 128,000 bbl. per day for the year 1937 and 143,400 bbl. per day for the month of February 1938.

Twenty-four wells were completed in Mexico during 1939 as compared to 34 completions in 1938 and 57 in 1937. With one exception, a wildcat completed as a dry hole by the Mexican Gulf in Maguey, San Luis Potosi, all wells were drilled in proven territory, most of them by the Government on locations previously made by the companies. Results were 14 producers and 10 failures.

Northern District (*Panuco or Heavy Crude*).—In the Northern district, 3 producers and 5 failures were completed in 1939, as compared with 5 producers and 11 failures in 1938. These producers are estimated to total an initial production of 2300 bbl. per day, but as the field as a whole has been produced at only about 50 per cent of the potential for the year, this new production was not required.

Southern District (*Golden Lane—Light Crude*).—No wells were drilled in the Southern district during 1939. Production averaged about 50 per cent of potential for the year.

The Mexican Gulf completed No. 1 Maguey in the Tempoal Valley, west of the Southern district, as a dry hole at 8076 ft. A good show of light oil was encountered around 3850 ft. but the Government ignored a request for an extension of the drilling permit to allow testing and the company was forced to abandon the well.

Poza Rica (*Light Crude*).—Seven wells were completed in Poza Rica. Results were five producers with an estimated total initial production of 22,500 bbl. per day and two failures—one a dry hole drilled in Potrero y Ojital adjoining Poza Rica to the south and the other a "junked" hole drilled by the Government on the crest of the Poza Rica structure.

TABLE 2.—*Oil and Gas Production in Republic of Mexico*

Line Number	Field	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1939	During 1939[1]
1	Northern district	1901	400,000	746,013,000	5,508,000
2	Southern district	1910	21,500	1,024,000,000	4,652,000
3	Poza Rica district	1930	13,300	95,831,000	23,072,000
4	Isthmus of Tehuantepec	1909	10,000y	105,649,000	6,247,000
5	Northern Mexico	1931	5,000y	0	0
6	Total		449,800y	1,971,493,000	42,479,000

[1] December 1939 estimated.

Production in the area was increased from 55,000 bbl. per day in January to 89,600 by October, dropped to 75,000 bbl. per day in November and to an estimated 55,000 in December. With the 1939 completions, potential production of Poza Rica is estimated at a minimum of 100,000 bbl. per day.

Isthmus of Tehuantepec (Light Crude).—Eight wells were completed in the Isthmus, all in the proved area of El Plan dome. Two failures and six producers resulted, the latter with a total initial production of about 2500 bbl. per day.

Produced at 21,000 bbl. per day in January, the Isthmus production averaged 16,000 to 17,000 bbl. per day during the last half of the year. Although never flowed to capacity by the Aguila, the present operators cannot produce sufficient crude for the requirements of the Isthmus Minatitlan refinery and take in Poza Rica crude by tanker to make up the deficiency.

Northeastern Mexico (Only Gas Produced to Date).—No wells were completed in northeastern Mexico during 1939. A deep test for oil on La Presa anticline near Mier, Tamaulipas, is in progress by the Ohio-Mex, and one other well for gas production is being drilled on the adjacent La Lajitas structure. Activities in general, however, have been suspended since March 18, 1938.

The export picture (Table 4) shows an increase of light crude exports from 5 per cent of the total exports in 1937 to 43 per cent of the total exports in 1939—while Mexican refining capacity remains unchanged. This reflects a direct economic loss to Mexico.

Exports to Germany accounted for 33.3 per cent of the total exports during 1939 (Table 5). The major portion of these shipments were made on a basis of 40 per cent cash, 60 per cent barter. The outbreak of the

TABLE 2.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Character of Oil	Producing Formation				
			During 1939		End of 1939			Number of Wells							
	To End of 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Gravity, A.P.I. at 60° F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Structure[h]
1	y	1,617	3	y	y	659y		659y	0	11–14	Tamasopa limestone	CreM	L		AF[2]
2	y	586	0	y	y	262y		262y	0	20–24	Elabra limestone	CreM	L	Cav y	AF[3]
3	y	29	5	y	4	25		25	0	30–32	Tam-Abra limestone	CreM	L	Por y	A[4]
4	y	352	6	y	y	200y		200y	0	23–33	Sands	Olig-Mio	S	Por y	DS[5]
5	y	12	0	y	y	0	12y	12y	0		Sands	Olig-Mio	S	Por y	A
6		2,596	14			1,146y	12y	1,158y							

[c] Footnotes to column heads and explanation of symbols are given on page 239.

[2] Producing from fractures in nonporous Cretaceous limestone.

[3] Producing from porous (reef phase) Cretaceous limestone.

[4] Producing from porous zone 500 ft. ± below top of Mid Cretaceous.

[5] Producing chiefly from Miocene with some Oligocene sands.

TABLE 3.—*Summary of Drilling Operations in Republic of Mexico*

Important Wildcats Drilled in 1939

	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
1	Lot 5, Hacienda Maguey, Municipality of Tampacan, State of San Luis Potosi	8,076	Tertiary	Bottom 166 ft. in Jurassic	Mexican Gulf	Dry hole*

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	8	0
Number of oil wells completed during 1939	14	0
Number of gas wells completed during 1939	0	0
Number of dry holes completed during 1939	9	1

* Gas blowout with 20–25 bbl. per day of 44° oil encountered at 3851 to 3859 ft. After waiting 3 months for permit to go back and test show (Government took no action) company abandoned hole.

war in Europe on Sept. 3 prohibited shipments to Germany and prevented delivery to Mexico of that portion of the German barter material still due in exchange for petroleum.

Exports to Italy are on a straight barter basis—oil for Italian-built tankers (to be delivered to Mexico in 1940) and rayon. The rayon is sold for cash in the Mexican market, to manufacturers of artificial silk textiles.

TABLE 4.—*Exports of Petroleum Crudes and Products from Mexico (Including Ship's Bunkers)*

THOUSANDS OF BARRELS

Classification	Year		
	1937	1938	1939
Northern crude (Panuco)	5,887	1,503	4,227
Southern crude	395	87	241
Poza Rica crude	874	3,025	7,071
Isthmus crude		62	803
Fuel oil	5,663	2,473	2,922
Gas oil	3,234	3,109	1,783
Gasoline	4,388	2,775	1,488
Kerosene	688	241	42
Lubricants	400	88	2
Asphalt	3,049	1,000	481
Total	24,578	14,363	19,060

Exports to the United States (Table 5) include 3,687,000 bbl. shipped to the Eastern States refinery in Texas to be processed and reexported.

TABLE 5.—*Destination of Petroleum Exports from Mexico*
THOUSANDS OF BARRELS

Destination	Year					
	1937		1938[a]		1939	
	Exports	Per Cent	Exports	Per Cent	Exports	Per Cent
Australia	705	2.9	161	1.1	123	0.6
Belgium	610	2.5	808	5.6	23	0.1
Brazil	419	1.7	48	0.3	126	0.7
Chile	213	0.9	5		54	0.3
Cuba	485	2.0	292	2.0		
Dutch West Indies	4,299	17.5	1,097	7.6		
England	5,411	22.0	1,857	12.9	19	0.1
France	156	0.6	243	1.7	16	0.1
Germany	2,521	10.3	5,408	37.7	6,343	33.3[b]
Guatemala	131	0.5	1			
Italy	186	0.8	350	2.5	4,790	25.1
Japan			233	1.6	188	1.0
Scandinavia	352	1.4	365	2.6	398	2.1
South Africa	162	0.7				
United States	6,856	27.8	2,683	18.7	5,456	28.6[c]
Uruguay	70	0.3	69	0.5	226	1.2
Others	488	2.0	265	1.9	308	1.6
Bunkers	1,514	6.1	478	3.3	990	5.2
Total	24,578	100.0	14,363	100.0	19,060	100.0

[a] Jan. 1 to March 18 under company management. Seized properties operated by Mexican Government after March 18.

[b] Exports to Germany for 8-month period. No shipments after Sept. 1 because of English-French blockade.

[c] Includes 3,687,000 bbl. shipped in bond to Eastern States refinery at Houston, Texas, for re-export.

Mexico imported 106,000 bbl. of gasoline for domestic use from this source in December 1939. The remainder of the products exported from Eastern States went chiefly to Italy and Germany, Italy receiving about 50 per cent of the total.

PRICES AND TAXES

The disposal of crude and products from seized properties resulted in a wide range of prices for identical items, depending on the terms of the sale—cash, barter, or both.

Panuco crude has been the only petroleum product sold on the open market by independents still operating in Mexico, and the price of the last cargo sold in 1939 was $0.68 per barrel—as compared with $1.00 in

1935, $0.95 in 1936 and ranging from $1.35 to $0.96 in 1937. In December 1939 three cargoes of Panuco crude brought three different prices —sale by the Mexican Government to Italy of "expropriated" oil, $0.92; sale by Mexican Gulf company to the Gulf company in the United States of their own "unexpropriated" oil, $0.63; sale by Empire company to Mexusa, Holanda Corporation, of Empire's "expropriated" oil (in private deal with the Mexican Government), $0.505.

At the close of the year Poza Rica crude was being sold by the Mexican Government for export at $0.70 to $0.95 per barrel, depending upon the buyer. Isthmus crude sold for $0.95 per barrel (to Italy) and Southern crude for $0.55 per barrel to the affiliated Eastern States refinery.

TABLE 6.—*Petroleum Export and Production Taxes*
U. S. CENTS PER BARREL

Classification	Dec. 1936	Dec. 1937	Nov. 1938	Feb. 1939	Sept. 1939	Nov. 1939
Heavy crude	11.7	12.7	9.0	8.6	11.0	10.2
Light crude	18.8	20.4	13.9	14.0	17.6	16.6
Fuel oil	16.8	18.4	12.5	12.6	16.2	15.1
Crude gasoline	25.2	25.7	20.9	20.5	22.7	21.0
Refined gasoline	11.7	12.0	9.7	9.5	10.5	9.7
Crude kerosene	15.2	19.0	14.9	15.0	15.8	14.9
Refined kerosene	7.4	9.3	7.1	7.1	7.6	7.1
Official rate of exchange, pesos for $1.00	3.60	3.60	4.90	4.90	4.95	4.95

Export and production taxes for the years 1936 through 1939 are given in Table 6. During that period the value of the peso with relation to the dollar dropped 37 per cent, while the taxes on a U. S. currency basis averaged 10 per cent less in November 1939 than in December 1936. In addition to these old taxes, the Mexican Government in August 1938 declared a 12 per cent ad valorem tax on all exports (Table 7). Apparently to offset depreciation of the peso, this tax is adjusted from

TABLE 7.—12 *Per Cent Ad Valorem Tax on Petroleum Exports*
U. S. CENTS PER BARREL

Classification	Jan. 1939	Dec. 1939	Classification	Jan. 1939	Dec. 1939
Heavy crude	8.4	8.5	Refined gasoline	16.3	19.0
Light crude	8.8	11.1	Crude kerosene	18.1	20.0
Fuel oil	8.2	9.5	Refined kerosene	16.2	18.0
Gas oil	19.4	18.5	Asphalt	16.6	18.8
Crude gasoline	11.0	13.9			

time to time by revaluation of export items. During December 1939, the peso dropped from 4.95 to 6.00 with relation to the dollar. It is interesting to note that the Mexican Government posted new valuations of petroleum products on Jan. 16, 1940, increasing all items an average of about 20 per cent—effecting a corresponding 20 per cent tax increase—to offset the decline of the peso.

Petroleum Developments in Peru during 1939

By O. B. Hopkins,* Member A.I.M.E.

(New York Meeting, February 1940)

Petroleum activities during 1939 are conveniently divisible into three parts: development, exploration, and leasing.

Development

Essentially all production for Peru came from the three established fields in coastal northwestern Peru (Fig. 1). These fields are known as La Brea-Parinas, Lobitos, and Zorritos, in order of importance. Together they produced 13,496,880 bbl., as compared with 15,838,605 bbl. in 1938.

Zorritos Field.—Of the total production shown on Table 1, the Zorritos field was responsible for a relatively negligible amount estimated at 40,000 bbl. This small field, which is over 50 years old, was purchased by the Peruvian Government in the spring of 1939 from the Piaggio interests. The Government operated this field along with its near-by National Reserve areas, largely under supervision of Department of Mines officials, and the total production rate for both old and new areas was estimated to have increased by Oct. 1 to 166 bbl. per day, as compared with the 1938 average of 110 bbl. per day. Construction is said to have begun on a refinery that is to have a capacity of 1000 bbl. per day and is to include a gasoline-extraction plant, and on a pipe line to bring fresh water 20 miles from the Tumbes River.

Lobitos Fields.—The Lobitos fields, some 70 miles south of Zorritos, produced approximately 2,650,000 bbl., or almost the same amount as in 1938.

La Brea-Parinas.—The International's La Brea-Parinas property, immediately south of the Lobitos property, produced 10,806,880 bbl., or 80 per cent of Peru's production. During the year 73 wells were drilled on the Estate, mostly in the semiproved area: 44 by rotary, 13 by cable and 16 by star rigs, as compared with 34 by rotary, 11 by cable and 20 by star in 1938. The most important of the several semiexploratory wells sunk was No. 3075, which late in December was brought in at a depth of 4500 ft. with an initial production of 1500 bbl. per day, based on

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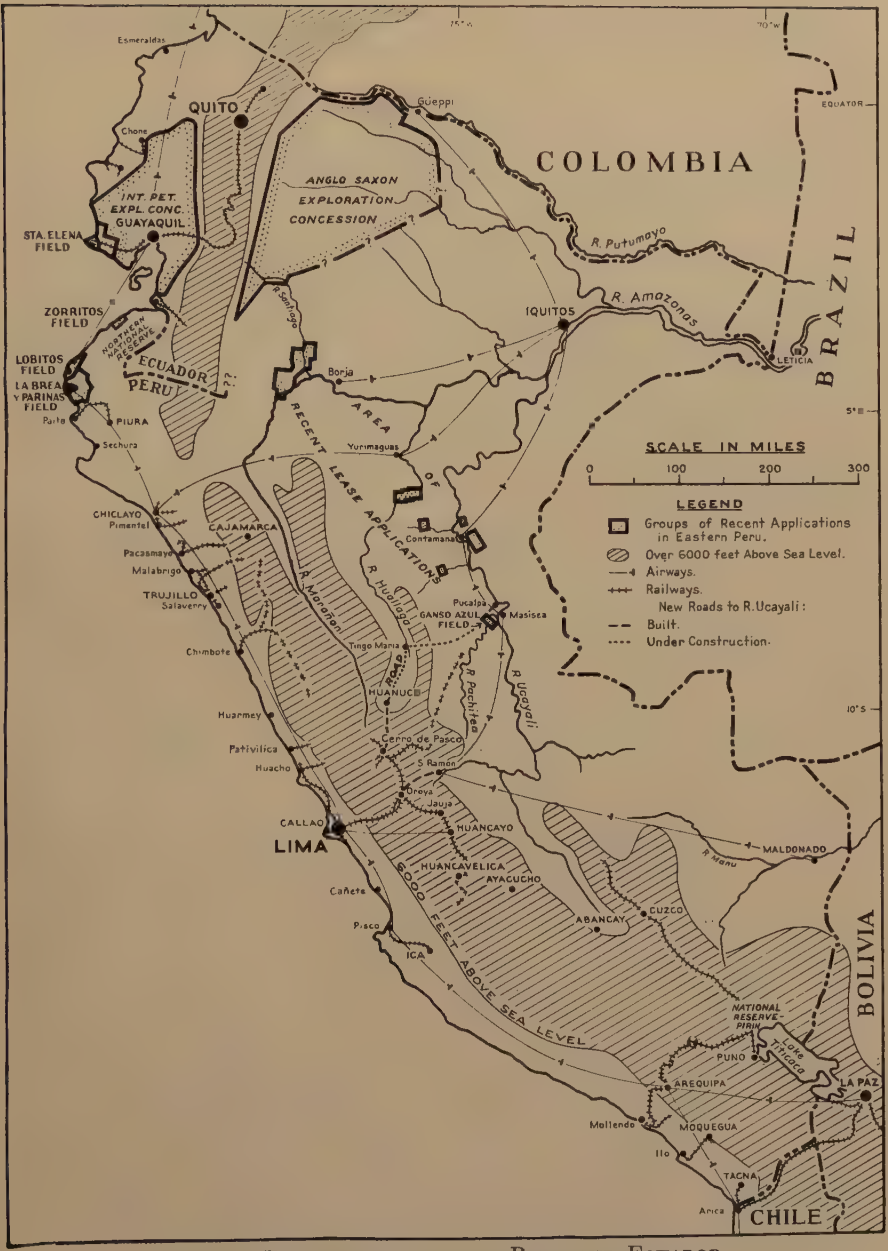

FIG. 1.—DEVELOPMENT MAP OF PERU AND ECUADOR.

a short test. At the end of 1939 there were 1993 wells still classed as producers out of a total of 3111 wells completed to that date.

EXPLORATION

Zorritos and Pirin.—The Peruvian Government continued its drilling in two widely separated regions. In the northern National Reserve region and the adjoining Zorritos field, up to Oct. 1, it had drilled a total of 14 wells and had 5 rigs in operation. The largest production found was 50 bbl. per day, but by October this well had already declined to 25 bbl. per day. On the National Reserve in the Pirin region, adjoining Lake Titicaca, it abandoned one well, has one well producing oil and water, and one well drilling.

Pachitea Region.—In eastern Peru the outstanding wildcat of the year was completed by the Cia. Ganso Azul, which brought in its Agua Caliente 1A on Feb. 26 at 1174 ft., with an initial yield of 750 bbl. per day of 45° gravity oil from a lower Cretaceous horizon. The productive structure is reported to be an anticline 16 miles long by 7 miles wide, with dips averaging 20°. It is said to have 3600 ft. of closure and to include 50,000 acres within the closing contours. The discovery well is on a 90,000-acre concession 20 miles above the confluence of the Pachitea River with the Ucayali River (Fig. 1). The concession is 3000 miles by water from the mouth of the Amazon and 300 miles northeast of Lima. Most of the journey from Lima can be made by motor in two days, or the entire trip can be made by plane in one day, crossing the Andes at an altitude of more than 15,000 feet.

TABLE 1.—*Oil and Gas Production in Peru*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939	
										During 1939		End of 1939			Number of Wells	
			Oil	Gas[b]	To End of 1939	During 1939	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
1	LaBrea-Parinas, *Piura*..	1889	*y*	*y*	202,335,635	10,806,880	*x*	*x*	3,111	73	17	90	1,885	18	88	1,788
2	Lobitos and Restin, *Piura*	1904	*y*	*y*	46,627,405	2,650,000	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
3	Zorritos, *Tumbes*........	1883	*y*	*y*	3,223,362	40,000	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
4	Pirin (Huacane), *Puno*[1]..	*x*	*y*	*y*	*y*	*y*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
5	Pachitea, *Huanuco*[1].....	1939	*y*	*y*	*y*	*y*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
6	Totals...............				252,186,402+	13,496,880+										

[b] Footnotes for column heads and explanation of symbols are given on page 239.

[1] Oil and gas production of these fields believed to be negligible. Small quantities may have been used in tests or for fuel

A third well a mile northwest of the discovery well is now drilling. Consideration is being given to erecting a 1000-bbl. refinery.

LEASING

Approximately 278,000 hectares, or about 700,000 acres, of oil leases were recently applied for in eastern Peru in the form of 16 concessions.

ECUADOR

In attempting to evaluate the relative position that Peru may occupy in the future in the oil industry of the west coast of South America, the oil developments in neighboring countries should be kept in mind. At present the more important of these appear to be in Ecuador, where the Anglo-Saxon is exploring a 25,000,000-acre concession in the Oriente, and where International is doing geophysical work on a 4-yr. exploration concession of 10,000,000 acres, centered on the port of Guayaquil. For the past few years Ecuador's total production has come from the Santa Elena peninsula and has averaged something over 2,000,000 bbl. annually.

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.		Repressuring Operations[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1939	
										Depth, Avg. Ft.					
	Initial	Avg. at End of 1939		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	y	y	PM RP	38.0	y	Verdun, Talara Parinas, Salina, Negritos	Eocene	S	y	y	y	y	AF	Eocene	
2	y	y	y	y	y	Terebratula, Lower Caverno	Eocene	S	y	y	y	y	AF	Probably Cretaceous	
3	y	y	y	y	y	Zorritos	Miocene	S	y	y	y	y	MF?	y	
4	y	y	y	y	y	y	y	y	y	y	y	y	y	y	
5	y	y	y	y	y	y	y	y	y	y	y	y	A	Lower Cretaceous	3,100
6															

Oil and Gas Production in Poland

By Eugene Jablonski*

(New York Meeting, February 1940)

Statistical data on the Polish producing business are available only for the first half of 1939. Because of the invasion of the country during September by Germany and Russia all sources of information have stopped, and it is impossible to get even an approximate picture of the status of the industry after that date.

The long declining trend of Polish production, which was finally checked during 1938, kept a further upward tendency during the first half of 1939, and there is good reason to believe that the upward trend would have been maintained.

It is true, there was little hope of reviving the slowly dying Boryslaw field, although there still remained a slight possibility for an extension in its southwestern direction. Repressuring plans were still discussed, but could not be put into effect because of extremely complicated and split-up lease ownership. The Gorlice-Lipinki field continued to be the main factor in the increase of the country's production. During the first half of 1939 this field received a further important extension in a southern direction. The Schodnica field continued to use repressuring with success.

At the end of June, 21 exploratory wells were drilling, 14 of which were within the Carpathians and 7 in the Miocene geosyncline of the Carpathian Foreland. All of the wildcat wells drilled within the Carpathians were on the structural extension of old established fields, but part of the wildcats of the Foreland were on new geological and geophysical prospects.

The Opary gas field of the Foreland discovered last year has been further developed. The Government-owned Polmin completed its third gasser. This well penetrated two sands; the upper one, 118 ft. thick, was found at 1312 ft., with an initial pressure of 570 lb. and capable of producing 10 million cu. ft. per day. The second sand, 91 ft. thick, was found at 1690 ft., yielding 20 million cu. ft., with a pressure of 760 lb. The well Mieczyslaw, drilled about 3 miles further north on the flank of the structure, found the first sand watered.

The Pioneer No. 5, at Chodonice near Przemysl, which reported some gas last year, was 5696 ft. deep at the end of June, still drilling in Miocene. Another well in the same vicinity drilled by the Gasolina was 1708 ft. deep.

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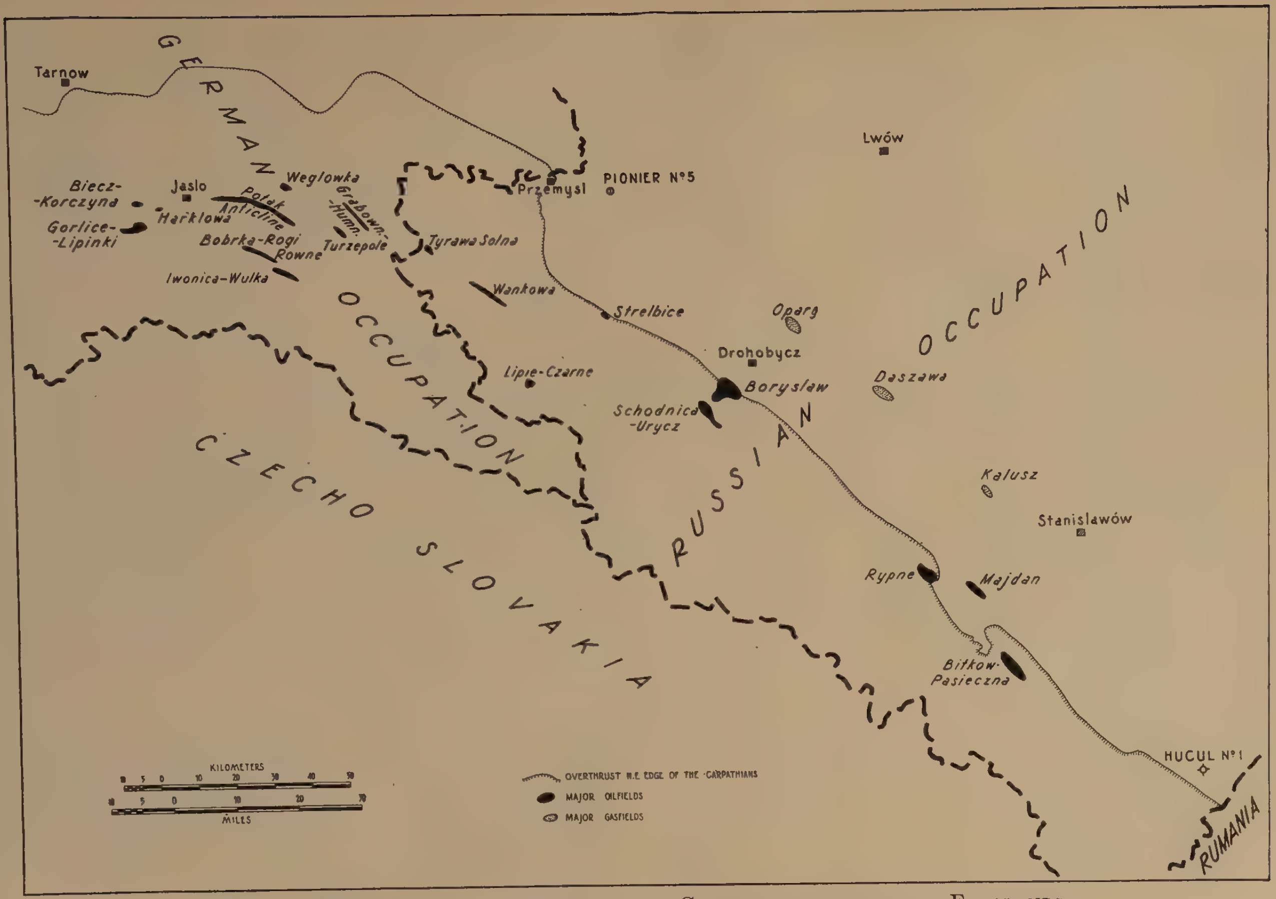

FIG. 1.—POLISH OIL AND GAS FIELDS, IN THE CARPATHIANS AND ON THE FORELANDS.

The important Hucul well, drilled at Wierzbowiec, close to the Rumanian border on the eastern end of the Foreland, was abandoned in April as a dry hole in the Cretaceous at a depth of 5085 feet.

The possibilities of discovering German type oil fields on the flanks of salt domes in the North Polish Plains have been further under consideration by the Geological Survey of Poland, and geophysical surveying and Government-subsidized drilling continued.

TABLE 1.—*Oil and Gas Production in Poland*

Line Number	Field	Area Proved, Acres		Total Oil Production, Bbl.		Daily Avg. June 1939	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells		
		Oil	Gas[b]	To End of June 1939[3]	During First Half of 1939		To End of June 1939	During First Half of 1939	Completed to End of June 1939	During First Half of 1939: Completed	During First Half of 1939: Abandoned
	FIELDS WEST OF THE SAN RIVER										
1	Gorlice-Lipinki	1,182	*y*	5,288,594	266,730	1,519	*x*	98.3	1,101	65	4
2	Biecz-Korczyna	65	*y*	418,205	15,345	78	*x*	26.8	59	1	
3	Harklowa	130	*y*	1,774,609	27,367	151	*x*	16.2	280	3	
4	Potok anticline	1,335	515	8,144,735	114,503	623	62,202.7	3,989.7	454	15	1
5	Bobrka-Rogi-Rowne	225	*y*	5,554,751	24,315	133	*x*	47.2	253		1
6	Iwonicz-Wulka	275	*y*	1,037,175	16,710	110	*x*	36.3	103	12	
7	Zmiennica-Turzepole	67	*y*	717,627	13,117	78	*x*	24.8	62		
8	Grabownica-Humniska	321	*y*	1,998,075	45,383	261	*x*	147.0	121	5	3
9	Weglowka	148	*y*	2,037,718	12,983	77	*x*	12.0	229	2	1
10	Minor western fields[1]	160	494	787,540	30,285	171	*x*	170.3	309	19	
	Total fields west of San River	3,908	1,009	25,759,029	566,738	3,201		4,568.6	2,971	122	10
	FIELDS EAST OF THE SAN RIVER										
11	Tyrawa Solna	50		52,972	13,140	67	*x*		42	2	
12	Lipie-Czarne	100		51,877	10,102	53	*x*	4.2	81	3	2
13	Wankowa-Paszowa	568		2,421,086	91,133	489	*x*	28.1	467	12	2
14	Strzelbice	62		629,143	9,315	58	*x*	3.8	75	1	
15	Boryslaw	3,700		182,280,769	872,386	4,788	198,377	2,044.6	1,317	14	
16	Schodnica-Urycz	1,110		20,420,596	182,677	1,035	*x*	199.7	840	18	
17	Daszawa gas field		1,500				58,377	3,639.0	35	3	
18	Rypne-Perehinsko	1,500		2,416,090	45,885	253	*x*	225.0	247	7	3
19	Majdan-Niebylow	260		261,652	17,040	109	*x*	3.0	133	14	3
20	Bitkow-Paszowa	1,480	250	6,469,839	97,755	573	38,031	683.2	390	6	4
21	Kalusz gas field		120	1,125	1,125			295.6	4	1	
22	Minor eastern fields[2]	145		7,186,936	9,668	59		29.5	319	4	1
23	Total fields east of San River	8,975	1,870	222,192,085	1,350,226	7,484		7,155.7	3,950	85	15
24	Total Poland	12,883	2,879	249,951,114	1,916,964	10,685		11,724.3	6,921	207	25

[b] Footnotes to column heads and explanation of symbols are given on page 239.

[1] Under "minor western fields" are included such fields as: Sekowa-Siary, Ropianka, Klimkowka, Strachocina-Gorki; also fields now under German occupation, but in previous years reported under Drohobycz district, such as Rajskie and Brzozowiec fields.

[2] Under "minor eastern fields" are included such fields as: Opaka, Opary gas field, Sloboda Rungurska.

[3] Polish official statistics give production in metric tons. A weighted average factor of 7.5 (corresponding to weighted average gravity 37° A.P.I.) has been used to convert tons into barrels, except for Boryslaw, for which a factor of 7.3 (33° A.P.I.) was used. In previous years a different factor (probably 7.0) was used.

Highly split-up surface ownership and artificially kept up high prices for crude oil were always and remained up to the time of occupation the two outstanding features of the Polish producing industry.

Boryslaw 33° gravity crude was quoted at Zl 1725 for a tank car, which means $4.49 per barrel, and the 46° gravity Starawies crude from the Grabowinca-Huminski field was quoted at Zl 2399 per tank car, which means $5.77 per barrel, accepting the value of the zloty to be what its official rate was; namely, 19¢ to the zloty. This high price for crude oil was maintained by prohibition of import of foreign crude and by government control of prices for refined products.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells			Oil-production Methods, End of June 1939		Reservoir Pressure, Lb. per Sq. in.		Character of Oil		Producing Formation						
	End of June 1939			Number of Wells												
Line Number	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939	Gravity A.P.I. at 60°F., Weighted Average	Paraffin, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft., Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]
FIELDS WEST OF THE SAN RIVER																
1	16	692	1		692		*x*	34	5.2	Ciezkowice	Eoc	S	22	2,700	80	Af
2	2	44			44		*x*	39	0.7	Ciezkowice	Eoc	S		1,440	120	AF
3	4	144			144		*x*	27	0.8	Krosno	Olig	S		1,066	150	AF
4	8	161	38	6	155	1,621	*x*	40	1.6	Ciezkowice	Eoc	S	12.2	3,900	126	AF, Af
5	2	91	3		91	853	*x*	34	3.3	Ciezkowice	Eoc	S		3,200	160	A
6	3	55			55	1,351	*x*	29	0.3	Ciezkowice Czarnorzeki	Eoc Cre	 S		 2,120	 100	 A
7		39			39		*x*	33	6.7	Ciezkowice	Eoc	S		2,400	100	A
8	5	54		2	52	711	*x*	47	3.0	Ciezkowice Czarnorzeki	Eoc Cre	 S	 19.5	 2,940	 200	 AF
9	3	85			85		*x*	30	0.4	Czarnorzeki	Cre	S		1,050	100	A, MC
10	46	221	6		221		*x*	38	0.4	Krosno	Olig	S		3,000	75	A, MC
	89	1,586	48	8	1,578											
FIELDS EAST OF THE SAN RIVER																
11	1	15			15		*x*	44	0.3	Lower Krosno	Olig	S		900	*y*	Af
12	6	25			25		*x*	42	5.1	Lower Krosno	Olig	S		1,310	*y*	Af
13	32	388	1		388		*x*	34	5.9	Lower Krosno	Olig	S		1,900	50	AF
14	3	40			40		*x*	32	6.2	Jamna	Eoc	S		660	45	A, MC
15	207	625	129		625		*x*	33	7.7	Boryslaw sand Hieroglyph Jamna	Olig Eoc	S	14.1	5,700	120	AF
16	93	602	1		602		*x*	36	3.2	Jamna	Eoc	S		1,480	150	Af
17	5		29			896	*x*			"Gas Series"	Mio	S	25.0	2,300	100	A
18	14	125			125		*x*	36	6.0	Kliwa	Olig	S		2,625	60	A, MC
19	12	93			93		*x*	30	0.9	Hieroglyph Inoceramus	Eoc Cre	 S		 1,920	 80	 Af
20	37	145	13	1	144		*x*	44	4.5	Kliwa	Olig	S		4,710	30	AF
21			4			900	900			"Gas Series"	Mio	S		*y*	*y*	*x*
22	54	83	3		83		*x*	36	5.5	Hieroglyph	Eoc	S		2,400	80	Af
23	464	2,141	180	1	2,140											
24	553	3,727	228	9	3,718											

As a result of the military occupation in September, Germany has obtained all fields lying west of the San River, whereas Russia came into possession of those lying east of the San River. In other words, Germany has obtained, with the exception of Tyrana Solna, the fields that belonged to the Jaslo district and Russia has obtained, with the exception of Brzozowiec-Mokre and Rajskie, the fields that were known as the Drohobycz and Stanislawow districts.

This has given Germany control over only a little more than one-fourth of Poland's production of crude oil. No statistics are available for the period after occupation, and there is little hope that reliable information will reach the outside world during the duration of the present war. It is of interest that Germany has obtained most of the production with upward tendency, whereas Russia has received the larger, but now rapidly declining portion of production, including the Boryslaw field. This feature is well illustrated in Table 2, which clearly shows that the steady decline of Polish production was checked in 1938, that this decline was due to the decline of the Boryslaw field, and that the Jaslo district, which more or less coincides with the German acquisition, had a steady upward trend during the last decade.

TABLE 2.—*Production of Oil in Poland*
METRIC TONS

Year	Jaslo District	Boryslaw Field	Rest of Poland	Total Poland
1929	73,610	470,570	124,330	668,510
1930	85,350	443,340	134,080	662,770
1931	97,650	390,700	141,930	630,280
1932	95,820	330,290	130,570	556,680
1933	96,450	325,140	129,080	550,670
1934	95,380	301,380	132,440	529,200
1935	99,080	285,980	129,700	514,760
1936	107,890	271,320	131,420	510,630
1937	117,690	258,860	124,750	501,300
1938	136,450	246,860	123,940	507,250
1939[1]	76,406	119,505	62,871	258,782
DAILY AVERAGE PRODUCTION, BBL.[2]				
First half 1938	2,760	4,988	2,517	10,265
Second half 1938	3,023	4,695	2,483	10,201
First half 1939	3,227	4,788	2,670	10,685

[1] Figures for 1939 are for only the first half year.

[2] Production figures in barrels are somewhat at variance with those reported in previous years because of the difference in factors used in converting metric tons to barrels.

It is probable that the production in the area under Russian occupation will continue to decline; and this decline will be accelerated by two factors: lack of price stimulus and inefficiency of Soviet control. The production in the area occupied by Germany will probably regain its upward tendency after a slight setback due to change in management; and this upward tendency will be accelerated by the tremendous demand caused by the war and the efficiency of German control.

Oil and Gas in Rumania

(New York Meeting, February 1940)

During 1939, there were no discoveries of oil and gas in Rumania worthy of mention, and the only important extension was the anticipated

TABLE 1.—*Oil and Gas Production in Rumania*

Line Number	Field, *District*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	Varful Draganesei, *Prahova*	1880	100		311,200	
2	Doicesti Sotanga, *Dambovita*	1912	100		22,600	
3	Glodeni, *Dambovita*	1897	200		568,500	9,000
4	Malul Rosu, *Dambovita*	1903	50		5,800	
5	Colibasi Resca, *Dambovita*	1856	700		3,243,300	
6	Pifigaia (Draganeasa), *Prahova*	1938	200		22,600	22,000
7	Campina, *Prahova*	1884	600		33,283,000	[210,000
8	Bustenari, Runcu, *Prahova*	1844	5,300		106,702,700	1,600,000
9	Scaiosi, *Prahova*	1929	200		81,500	9,000
10	Copaceni, *Prahova*	1904	200		1,884,400	90,000
11	Filipesti de Padure, *Prahova*	1910	270		2,037,300	
12	Magurele, *Prahova*	1938	100		10,000	7,500
13	Pacureti, *Prahova*	1899	150		230,500	
14	Matita, *Prahova*	1899	100		80,300	
15	West Gura Ocnitei, *Dambovita*	1929	7,600		70,190,800	3,810,000
16	Gorgota-Ochiuri, *Dambovita*	1913	1,000		42,949,200	1,950,000
17	Moreni, *Dambovita and Prahova*	1903	3,700		336,476,700	13,200,000
18	North Moreni, *Prahova*	1903	1,350		26.570,000	710,000
19	Piscuri, Piscuri North, *Prahova*	1927	500		21,[illegible]2,400	1,500,000
20	Ditesti, *Prahova*	1933	300		1,[illegible]29,800	
21	Calinesti, *Prahova*	1934	100		23,200	
22	Baicoi, Liliesti, Tintea, *Prahova*	1861	1,000		47,604,100	8,470,000
23	Bucsani, *Dambovita*	1933	3,900		33,953,100	2,350,000
24	Margineni, *Prahova*	1935	700		948,800	315,000
25	Aricesti, *Prahova*	1921	1,000		7,775,100	215,000
26	Boldesti, *Prahova*	1922	5,400		76,981,700	5,300,000
27	Ceptura, *Prahova*	1913	2,800		40,510,000	5,250,000
28	Orlea, *Prahova*	1932	50		11,200	
29	Podeni Noi, Apostolache, *Prahova*	1902	100		151,100	
30	Udresti, *Prahova*	1914	100		138,800	
31	Sarata Munteorul, *Buzau*	1869	250		3,703,300	47,000
32	Arbanasi, *Buzau*	1869	400		15,909,300	260,000
33	Solont Stanesti, *Bacau*	1860	250		4,753,900	85,000
34	Zemes, Taslau, *Bacau*	1860	170		4,918,200	152,000
35	Moinesti, Lucacesti, *Bacau*	1860	270		2,871,700	75,000
36	Comanesti Grozesti, *Bacau*	1860	100		15,400	
37	Tescani Casin, *Bacau*	1860	300		975,700	11,600
38	Maramures, *Maramures*	1918	10		3,900	
39	Transylvanian Basin (13 Fields), Gas	1907		4,000		
40	Total		39,620	4,000	889,241,100	45,648,100

[b] Footnotes to column heads and explanation of symbols are given on page 239.

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western continuation of the Baicoi-Tintea south flank, which, however, adds relatively little to the reserves of the country.

Production during the year amounted to 45,640,100 bbl., against 48,984,200 bbl. for 1938, or a drop of 6.8 per cent. The decline as reported last year was 8 per cent. Rumania's peak year was in 1936, with a production of 65,062,293 bbl. The only fields showing gains over the year 1938 were Baicoi-Tintea and Ceptura, with increases of 43 and 5 per cent, respectively. The six major fields registering declines averaged a 23.5 per cent drop.

During the year, 855,000 ft. of hole were drilled by 150 wells, which, in comparison with the previous year, is a decrease of 106,000 ft., or 11 per cent. Most of the drilling took place in Baicoi-Tintea, Ceptura, Moreni, Ochiuri, and Margineni. Averages of about 15, 7, 8, 6, and 3

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[e]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity, A.P.I. at 60°F., Weighted Average	Sulphur Per Cent
1			32											40	
2			4											39	
3			6				1			1				39	
4			10											37	
5			30											37	
6			8				1		1					36	
7			284	3			67		1	66				41	
8			1,649	8	10	45	550	2	6	546				42	
9			9					4		4				40	
10			20	1		2	8		1	7				41	
11			57											43	
12			1		1									32	
13			14			1								52	
14			10											42	
15			328	6	20	25	125	4	10	119				33	
16			299	16	10	15	85	4	12	77				33	
17			1,232	21	15	40	456	6	20	442				33	
18			389	1	4	10	37		1	36				33	
19			143	3	1	30	78	1	10	69				33	
20			9			6								39	
21			4			3								33	
22			533	49	5	30	125		68	57	4,200	3,000		39	
23			145		10	15	80	1	7	74	1,500	400		38	
24			24	8	1	3	10	1	8	3	3,500	2,100		39	
25			59			10	10	5	6	9				35	
26			170	7	5	32	84	5	23	66	2,500	1,000		37	
27			246	22	2	30	125		24	101	2,000	1,000		34	
28			8	1	1	1								34	
29			19		1									33	
30			2			2								34	
31			40				4			4				38	
32			176				90			90				38	
33			193	1			83			83				43	
34			60				41			41				43	
35			40				15			15				43	
36			20											44	
37			66				12			12				43	
38															
39	159,000	9,000	71	1	2			30	30		750	450			
40			6,410	148	88	300	2,087	63	228	1,922					

strings, respectively, for these areas were occupied throughout the year drilling new wells.

Only seven wildcats were completed in 1939 and six drilling at the end of the year. Of the completions, two were obligations imposed by the State. Furthermore, all except one of the wildcats were located in areas where surface geology could be studied rather than in the plains, where geophysical methods are necessary in order to evaluate lands. In this region the subsurface is owned by the State.

Considering that there have been no major discoveries since that of Bucsani in 1934 and the deep Meotic in the Baicoi-Tintea field in 1937, the production of the country is holding up remarkably well through drilling in the known fields along with the development of minor extensions in

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top, Prod. Zone	Bottoms Prod. Wells				
1	Meotic	Pli	S		1,100	2,000	60	F	Meotic	2,000
2	Meotic	Pli	S		1,700	1,900	50	A	Helvetian	5,100
3	Meotic	Pli	S		1,000	2,000	40	A	Helvetian	2,800
4	Sarmatian	Mio	S		500	1,000	10	A	Sarmatian	1,000
5	Meotic	Pli	S		600	1,400	50	AF	Meotic	2,000
6	Helvetian	Mio	S		4,400	4,600	170	F	Helvetian	4,800
7	Meotic	Pli	S		700	1,200	140	MF	Helvetian	2,200
8	Meotic, Oligocene	Pli, Olig	S		100	2,500	160	F	Oligocene	7,800
9	Meotic	Pli	S		1,400	1,800	30	MF	Sarmatian	3,200
10	Meotic	Pli	S		700	2,200	50	F	Meotic	3,000
11	Meotic	Pli	S		3,200	3,800	30	A	Deep Meotic, Sarmatian	6,400
12	Meotic	Pli	S		7,300	7,500	5	F	Burdigalian (Mio)	8,800
13	Dacic, Pontic, Meotic	Pli	S		2,000	4,000	110	A	Meotic	4,000
14	Meotic	Pli	S		1,000	1,300	10	A	Meotic	1,300
15	Meotic	Pli	S		5,400	5,900	120	SA	Helvetian	6,500
16	Dacic, Meotic	Pli	S		1,300	4,000	150	SA	Helvetian	5,100
17	Dacic, Meotic	Pli	S		1,400	5,600	120	SA	Helvetian	5,700
18	Dacic, Meotic	Pli	S		1,000	4,000	80	SA	Helvetian	7,000
19	Dacic, Meotic	Pli	S		1,200	4,000	80	SA	Helvetian	4,000
20	Meotic	Pli	S		6,900	7,300	50	SA	Helvetian	7,300
21	Meotic	Pli	S		5,300	5,700	40	SA	Helvetian	5,700
22	Dacic, Meotic	Pli	S		600	8,800	170	FS	Meotic	8,800
23	Meotic	Pli	S		6,500	7,300	40	A	Meotic	7,300
24	Meotic, Helvetian	Pli	S		6,100	7,500	40	A	Helvetian	7,900
25	Meotic	Pli	S		5,500	7,400	30	SA	Meotic	7,400
26	Meotic	Pli	S	25	6,900	7,900	110	A	Meotic	9,100
27	Meotic	Pli	S		2,400	4,100	100	A	Sarmatian	6,300
28	Meotic	Pli	S		7,600	8,400	20	A	Meotic	11,000
29	Meotic	Pli	S		800	1,700	15	FS	Meotic	7,900
30	Meotic	Pli	S		2,200	2,400	15	A	Meotic	2,400
31	Meotic	Pli	S		200	1,000	40	A	Meotic	1,200
32	Meotic	Pli	S		800	2,200	80	A	Sarmatian	3,300
33	Oligocene	Olig	S		1,000	2,000	30	AF	Burdigalian (Miocene)	3,050
34		Olig	S		200	1,000	30	AF	Oligocene	1,500
35	Meotic, Oligocene, Eocene	Pli, Olig, Eoc	S		200	1,000	40	AF	Oligocene	3,500
36	Oligocene	Olig	S		600	2,200	10	AF	Senonian	2,400
37	Helvetian	Mio	S		500	1,500	60	A	Burdigalian	4,900
38	Sarmatian	Mio	S		600	1,800		D	Mediterranean	6,500
39	Sarmatian	Mio	S							
40										

TABLE 2.—*Summary of Drilling Operations in Rumania*

Important Wildcats Drilled in 1939

	Field, *District*	Well No.	Total Depth, Ft.	Surface Formation
	WELLS DRILLING ON JAN. 1, 1939, AND COMPLETED DURING 1939			
1	Margineni, *Prahova*	1	7,881	Levantine (Pli)
2	Orlea, *Prahova*	351	8,258	Levantine (Pli)
3	Surani, *Prahova*	1	4,784	Meotic (Pli)
4	Surani, *Prahova*	101	2,359	Meotic (Pli)
	WELLS STARTED DRILLING AND COMPLETED DURING 1939			
5	Malaesti, *Prahova*	1	8,537	Helvetian (Mio
6	Bratesti, *Dambovita*	1	5,709	Levantine (Pli)
7	Tarlesti, *Prahova*	1	2,218	Meotic (Pli)
	WELLS DRILLING ON DECEMBER 31, 1939			
8	Tescani, *Bacau*	1	+4,925	Helvetian
9	Berca, *Buzau*	1	+7,458	Pontic
10	Doicesti, *Dambovita*	10	+4,541	Pontic
11	Campinita, *Prahova*	1	+ 715	Helvetian
12	Magurele, *Prahova*	2	+4,364	Sarmatian
13	Magurele, *Prahova*	3	+5,135	Sarmatian

Important Wildcats Drilled in 1939

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
	WELLS DRILLING ON JAN. 1, 1939, AND COMPLETED DURING 1939							
1	Sarmatian (Mio)	Romano-Americana Sospiro	700	0.2	¼	410	470	
2	Meotic (Pli)	Credit-Minier						Dry
3	Oligocene	Romano-Americana						Dry
4	Oligocene	Romano-Americana						Dry
	WELLS STARTED DRILLING AND COMPLETED DURING 1939							
5	Meotic (Pli)	Astra-Romana						Drilling abandoned
6	Pontic (Pli)	Unirea						Drilling abandoned
7	Oligocene	Romano-Americana						Drilling abandoned
	WELLS DRILLING ON DECEMBER 31, 1939							
8		Romano-Americana						Suspended
9		Astra-Romana						
10		Astra-Romana						
11		Astra-Romana						Suspended
12		Credit-Minier Neo-Petrol						
13		Credit-Minier Neo-Petrol						

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	26	6
Number of oil wells completed during 1939	145	7
Number of gas wells completed during 1939	3	
Number of dry holes completed during 1939	15	6

several areas. However, the end of the known fields is definitely in sight, and unless deeper production is found in the present fields, or fill-in fields within the present oil area are discovered, Rumania's production will be merely a question of decline. It is generally conceded that the plains' portion of the basin has possibilities of developing fields, and for years the companies have been trying to get a mining law that would permit their obtaining from the State sufficient reward in land to compensate the more expensive exploration and development. During the past year, the new law was expected from month to month, but is still in the course of study. It is said that the regulations will be favorable, but in any event several years will lapse before the country can be helped materially through increased production.

From a technical standpoint, steady progress is being made in the drilling, production and refining departments. The destructive competitive feature has been lessened to a marked degree through intercompany cooperation and State regulations, which protect in a fair manner individual leaseholders.

Russian Oil Industry in 1939

By Basil B. Zavoico,* Member A.I.M.E.

(New York Meeting, February 1940)

Production of crude oil in the U. S. S. R. during 1939 is estimated at 226,111,000 bbl., as compared with 219,778,000 bbl. in 1938, an increase of 2.88 per cent but some 6.00 per cent under the planned output. During the past year a major readjustment took place in Russian oil fields, with the Grozny district falling into the third place, its former place having been taken by the fields of the Maikop-Kuban area of northwestern Caucasus. Production continued to grow in the Ural-Volga district and further large increases in this province in the coming years are certain.

The drilling operations continued to be most unsatisfactory, falling far behind the plan, possibly as much as 25 per cent under the set objectives, and thereby interfering with the production plans, more particularly since the Soviet oil industry is still based primarily upon the production from the naturally flowing wells without any proration whatsoever rather than upon stabilized production from either prorated oil wells or those operated with various mechanical lifts. The year 1939 started with the fulfillment of the drilling programs to the extent of about 90 per cent, but the situation rapidly deteriorated and by the second half drilling programs were being fulfilled only to the extent of 60 per cent or less. Such breakdown in drilling operations was possibly due to poor equipment, which has not been able to stand increasing demands upon it, and this is substantiated by the recent orders placed in the United States by the Soviet Government for some 60 drilling rigs of the latest design.

PRODUCTION

Baku District.—The fields of the Apsheron Peninsula (Baku district) made a notable progress during the past year and were able slightly to increase their production, to 166,000,000 bbl. as compared with 164,692,000 bbl. during 1938. The emphasis of production in the Baku district remained on the flowing wells, about 20 per cent of the total number of wells flowing about 70 per cent of production. During 1939 some 550 wells were completed in the Baku district with active rigs averaging

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approximately 160. Producing practices remained highly ineffective and in addition to reliance of the management on the flowing production and the relatively little attention paid to the pumping wells much of the production was still of not fully closed-in type, with the result that excessive losses of light fractions continued. It should be noted that the Soviet engineers anticipate that the current yields of gasoline from many fields that average only 2.5 per cent could be increased to 7 per cent by more effective handling of crude oil on the way from wells to the refineries. The more important developments on the Apsheron Peninsula that will serve to prolong its life for many more years have taken place primarily in and around the older areas and in their immediate extensions. The Bibi-Eibat field was extended to the southeast in the deep Sub-Kirmaku sands, with wells producing initially up to 4500 bbl. per day; this extension adds considerable area to this already most outstanding field. Of the older fields the Surakhani has been extended in the northern direction, also in the Sub-Kirmaku sands; the discovery well in this area produced 3000 bbl. per day initially from 8550 ft. Surakhani field remains at this time still one of the principal producers of the Baku area, with a daily output of around 70,000 bbl.

Perhaps the most important development of the year on the Apsheron Peninsula took place between Binagady and Lok-Batan fields. This area, situated along a major structural axis, has not been promising in the shallow formations of the Pliocene "Oil Measures," but last year's developments of this area in the Sub-Kirmaku deep zone of these "Measures" have proved it to be potentially one of the richest discoveries made on the Peninsula. The first indication of the possibilities was given in January 1939, when the discovery well in the Yassamal Valley came in for about 2200 bbl. per day initially from around 5000 ft. Subsequent development in this area was somewhat disappointing, primarily, however, because of the inability of drillers to complete wells effectively. By the end of the year in this trend several other discoveries of major importance were made, including those at Chakhnagliar, Khodja-Khasan, Baladjari and others, the Sub-Kirmaku sands being found in this area at depth from 4000 to 5000 ft., and all furnishing flowing wells with capacities ranging up to 3000 bbl. per well per day. Farther south from Puta on the Kara-Dag structure, apparently a major field was opened, the discovery well flowing initially 4000 bbl. from 5340 ft. Also in this area first production in the Apsheron Peninsula from Maikop sand series was obtained, this formation being also in Pliocene but below the currently producing "Oil Measures"; the discovery well being drilled in Siazan-Naradaran and producing 225 bbl. initially. On the eastern end of the Apsheron Peninsula the importance of the Kala field was greatly enhanced by the discovery of production on the south half of the structure, formerly nonproductive, the first well in this area, one mile south from the North

Kala field, producing 400 bbl. per day initially from 7825 ft. Farther east, on Artem Island, favorable developments continued, this field becoming gradually of very considerable importance, which will be further accentuated during 1940 with the completion of a causeway to the mainland, a distance of about 1½ miles.

North Caucasus.—In the Grozny area of North Caucasus conditions continued to deteriorate, owing primarily, if not exclusively, to complete breakdown in drilling operations and to the inability of the management to handle production by mechanical means, while the discoveries of recent years have been produced so wastefully that practically all the natural flowing oil production had been exhausted by 1939. The Soviet plan placed too much dependence upon the area of the Old Grozny field in which drilling had for its objective the sands under the overthrust, where the formations lie deep at an angle of 60° to 90° and drilling under Soviet practices is obviously extremely difficult. Another mistake possibly being made in this area is the development of the sharply folded structures in the foothills of the mountains; under the Soviet somewhat backward drilling technique much more effective results could be obtained in the area farther away from the mountains, where the folds are considerably gentler and in which drilling conditions would be easier for crews not fully experienced in modern drilling operations.

Maikop-Kuban District.—Maineft (Maikop-Kuban) district, which during 1939 produced approximately 18,250,000 bbl., as compared with 13,500,000 bbl. in 1938, was able to make such an outstanding record only because of flowing production in some of the newer fields, notably the Shirokaia Balka. It is not anticipated, however, that production during the coming year will be maintained at the level of 1939, since flowing wells in this area have been very definitely overproduced and rapid declines are likely to set in early in 1940. However, the undrilled structures in this province already known and partly proved are many and it is not to be doubted that in the coming years this area will continue to gain in its relative importance in the Soviet Union if and when drilling development is more effectively handled.

Ural-Volga Permian Basin.—Outstanding discoveries during the past year were also made in the Ural-Volga Permian Basin, the district producing in 1939 some 14,300,000 bbl., of which the principal amount came from the Ishimbaevo field. That field had a major extension to the south late in 1938, which was largely responsible for increases in production, and in 1939 produced some 12,000,000 bbl. Elsewhere in this province important discoveries have been made in Samarski Luki area of the Volga River but developments there are being held up by delays in drilling. Due north from the Ishimbaevo, in the Perm district, additional wildcatting uncovered at least three other major fields of Krasnokamsk type, these new proven prospects being known as North

Kamsk, Polazni and Nitva. Oil and gas have been found in various quantities in a number of wildcats scattered throughout this immense area from Perm to the Caspian Sea on both sides of the Volga River but the distances involved and the slowness of new development do not at this time permit proper evaluation of the new showings.

Emba District.—In the Emba district apparently a new and important field was discovered in the southern portion, on the Kul-Sari salt dome, the discovery well flowing 700 bbl. initially from 3280 ft. The crude oil from this well is of exceptionally good quality, showing 75 per cent of light fractions with most of the residue lubricating stock of the highest quality. This discovery has been adjudged one of the most important in the area and is near enough to the existing pipe line to Orsk to be developed immediately.

Exploration and Prospects

During 1939 first production was obtained in central southern Russia on the Romni salt dome, the discovery well producing from 3780 ft. Additional domes have been found in this area from Romni to Poltava and more active exploration is under way. West of this area Soviet Russia has acquired through the Polish campaign about 75 per cent of former Polish production, which in 1938 amounted to roughly 2,600,000 bbl. The Soviet Government plans to make a detailed survey of this area with a view to increasing its production, more particularly, it is presumed, with the idea of supplying some of the central European markets.

In the Middle Asia province exploration has been very satisfactory from Cheleken Island to the Fergana Valley, but again the slowness of the drilling and the distances from the markets with inefficient transportation methods have held up more rapid progress, quite necessary in view of the development in this area of a large cotton-growing base.

With the active development of Siberia industrially, a large demand for petroleum products has been opened there and considerable effort is being made now to discover oil reserves in that immense territory. The Far East is at this time reasonably self-sufficient with the Sakhalin Island production, but the type of crude produced there does not supply a sufficient amount of gasoline for requirements of that area for both civil and military purposes, therefore some gasoline must be imported into Vladivostok from the United States, such transportation being much more economical than shipping around the Suez Canal and the Indian Ocean. Promising results have been obtained at several localities in Siberia but no commercial production has been developed or indicated. The most promising area is probably immediately east of the Ural Mountains and the exploration there is scheduled to become active only during the coming year. Perhaps the outstanding single factor about the geological exploration for oil in Siberia is the wide distribution of oil showings in the sediments of the Cambrian age and also the finding of oil seepages and of the live oil in the shallow oil wells in gneiss in the area of Lake Baikal. In the latter case, however, it is suspected that gneiss overlies a great thickness of sediments and the oil has seeped through the fractures, therefore the plans for the wildcatting in the coming year are to attempt to drill through the igneous material.

Elsewhere in Russia promising shows of commercial production have been obtained at a number of localities, indicating the immense wealth of the country in crude oil and gas reserves. In the north in the Ukhta district development is now approaching the island of Novaia Zemlia, in which, in addition to the possibilities of producing oil by more orthodox methods from oil wells, shafts are being sunk into very rich oil-saturated shale and sand beds that outcrop on the surface. The first commercial shaft to be completed during 1940 is scheduled to produce 4500 bbl. per day. Georgian fields in the Caucasus are also scheduled for commercial production during 1940, as are the more recent discoveries in the Crimea near Feodosia, where in November of 1939 a discovery well drilled by core-drill machine was completed at 420 ft. flowing at 175 bbl. per day from the Maikop series.

Petroleum Development in Saudi Arabia during 1939

By J. O. Nomland*

(New York Meeting, February 1940)

During the year 1939 the program of the California Arabian Standard Oil Co. in eastern Saudi Arabia consisted of drilling wells to increase the production of Dammam Dome. (This structure is also sometimes referred to as Dhahran Dome.) In addition, in other areas of the concession, wildcat wells are being drilled on geologically favorable structures. In the early wells drilled at Dhahran, production was at a depth of 2000 to 2200 ft. Since discovery of the "Arab zone" below 4300 ft., all of the later wells have been drilled to the deeper productive members. At present there are at Dhahran five wells in various stages of drilling or completion. In addition, 15 wells previously were drilled to the upper or lower zones. Although some of the early locations are exceptions, in general the spacing of the wells is at 3000 feet.

Prospect testing consisted in drilling one well at Abu Hadriya and one at Ma'agala, about 100 miles northwest and 120 miles west of Dhahran. The first had attained a depth of 8655 ft. without encountering the main Dammam productive zone, while the second was at a depth of 1372 ft. Both of these wildcat wells are on large dome structures.

Production.—During the year 3,933,903 bbl. of approximately 35° gravity oil was produced, all from flowing wells. A part of this production was shipped in barges to the refinery at Bahrein. In early May a 40-mile 10-in. pipe line was completed to the deep-water terminal at Ras Tanura. The ceremony of first opening the valve for flow of oil into an ocean tanker was performed by King Abdulaziz Ibn Saud. Since that time tanker shipments have continued, both to Bahrein and to world markets. Only sufficient gas for camp purposes has been produced.

Equipment.—A stabilization plant has been completed at Dhahran and plans have been made for a refinery at Ras Tanura. A modern camp is being built including power plant, central air-conditioning plant, radio station, employees' club and housing facilities for both married and single employees. Both the offices and dwellings are being air-conditioned. There is a hospital, with medical staff and nurses, providing facilities for both Saudi Arabs and Americans.

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General Prospecting

Geological activity has continued, consisting of surface field investigations, seismograph and gravity meter work, structure drilling, and extensive triangulation mapping. An engineering party has been assisting the Government in demarcation of the Iraq-Saudi Arab boundary.

The well being drilled on the west coast of Qatar Peninsula by the Petroleum Concessions Limited (Iraq Petroleum Co.) is stated stratigraphically to have a similarity to Bahrein. Oil showings have been reported. The Kuwait Oil Co. has completed three wells at Burgan, in the southern part of Kuwait. The production tests and size of the Burgan structure indicate that an important new oil field has been discovered.

Petroleum Developments in Venezuela during 1939

By D. B. Williams*

(New York Meeting, February 1940)

For the first time in the history of the Venezuelan petroleum industry production exceeded 200 million barrels. The total production for all fields amounted to 205,430,869 bbl., which is more than 9 per cent of the world's 1939 total. This is an increase of over 15 million barrels or 8.0 per cent above the 1938 figure, which, compared with the slightly less than 2 per cent increase of the 1938 figure over 1937, shows the marked activity in Venezuela during the past year.

The Maracaibo Lake fields are still the predominating factor in Venezuelan production, showing an increase of approximately 9½ million barrels over last year's figure and accounting for 71.8 per cent of Venezuela's total. Lagunillas continues to hold precedence as a single field, having yielded 47.1 per cent of the accumulative total and 34.4 per cent of 1939's total. This field showed an increase of slightly more than 3½ million barrels over 1938. Tia Juana, the second largest field, attained a record production, increasing its percentage of the Venezuelan total from 23.4 in 1938 to 23.7 in 1939. The La Rosa field, which includes Punta Benitez and Ambrosio, declined from 13.7 to 12.0 per cent; Bachaquero, the southernmost Lake field, which came into regular production at the end of 1938, contributed over 3⅓ million barrels.

Quiriquire, in eastern Venezuela, ousted La Rosa as the third largest producing field, and, although production increased by 1⅓ million barrels, percentage of the total declined from 13.2 to 12.9. Mene Grande, the oldest field, declined from 6.6 per cent in 1938 to 5.9 in 1939. Temblador produced for a whole year for the first time and yielded 3,647,867 bbl. The Colon district, in the Maracaibo Lake area, comprising the Tarra-Los Manueles fields, showed slight increases, as also did Cumarebo and Pedernales.

Construction of the 16-in. pipe line from Oficina to Puerto La Cruz (Guanta), the longest line of this size in the world, was completed toward the end of the year and this new field in eastern Venezuela started shipping oil in December. This field is operated by the Mene Grande Oil Co. and was credited with a production of 2,347,625 bbl. in 1939. Jusepin field, some 25 miles southwest of Quiriquire in eastern Venezuela,

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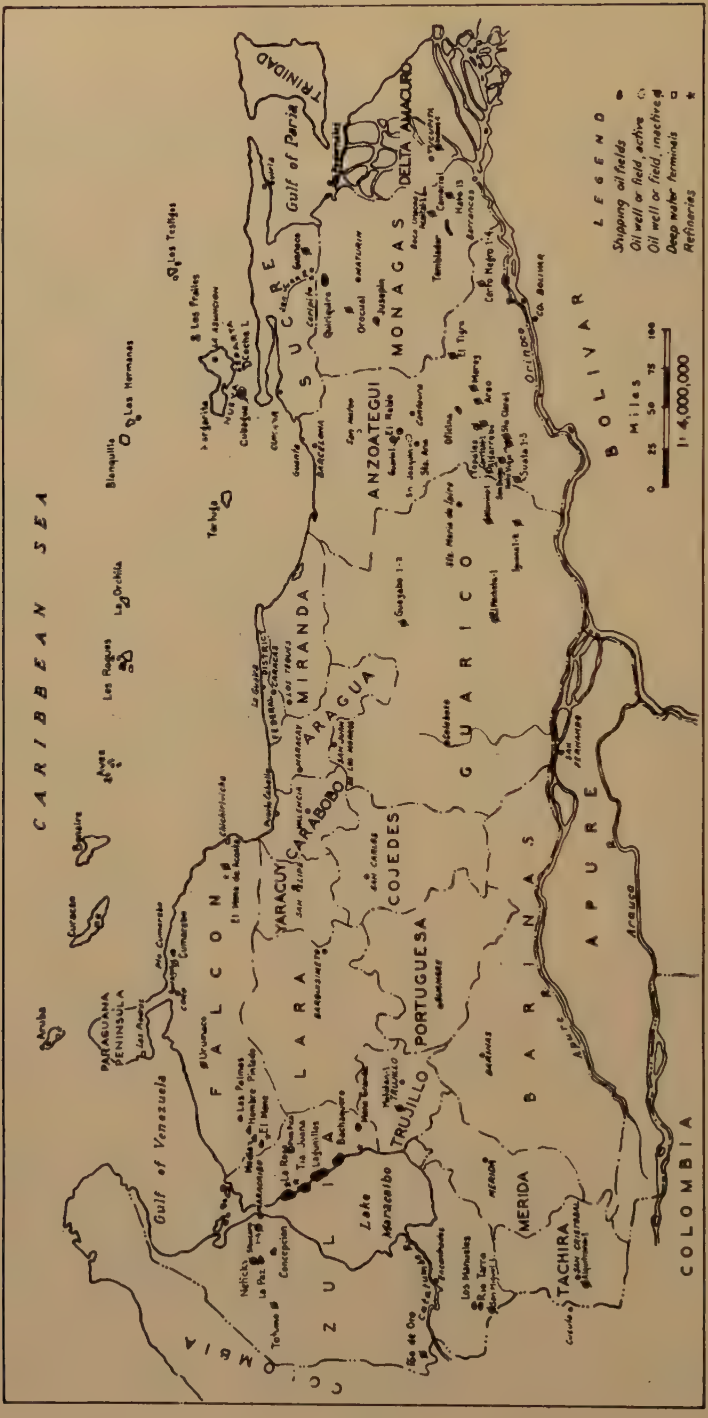

FIG. 1.—LOCATIONS OF OIL FIELDS IN VENEZUELA.

was put on a commercial producing status at the end of 1939 with the completion of a 40-mile 8-in. line to Caripito. This field, operated by the Standard Oil Company of Venezuela, was averaging slightly more than 6000 bbl. daily at the end of the year.

As will be seen from Table 1, the total production of Venezuela up to Dec. 31, 1939, amounted to 1,886,262,443 bbl. The percentage contributed by each of the principal fields for the past six years, together with their total to date, is given in Table 3. This statement shows that although the Maracaibo Basin is still the main source of Venezuelan production, its percentage of the total declined slightly in 1939, owing to the increased activity of new fields in eastern Venezuela.

TABLE 1.—*Oil and Gas Production in Venezuela*

Line Number	Field	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1939	During 1939
1	La Rosa/Punta Benitez	1917	35,545		364,921,308	24,687,184
2	Tia Juana	1927	18,101		118,302,711	48,758,913
3	Lagunillas	1925	42,946		888,672,893	70,600,109
4	Bachaquero	1930	16,274		4,372,965	3,382,620
5	Total Lake fields		112,866		1,376,269,877	147,428,826
6	Cumarebo	1931	500	*x*	24,522,412	2,667,326
7	El Mene	1922	1,040		21,411,082	364,763
8	El Mene de Acosta	1927	310		851,817	
9	Guanoco	1913	150		1,858,415	
10	Hombre Pintado	1929	*x*		839,383	494,743
11	Jusepin	1938	*x*	*x*	516,116	512,296
12	La Concepcion	1925	1,200		20,941,652	879,156
13	La Paz	1925	350		5,225,294	522,098
14	Las Palmas	1928	50	*x*	306,158	59,506
15	Los Manueles	1927	450		17,961,596	1,708,383
16	Media	1932	45		2,566,622	61,432
17	Mene Grande	1913	6,040		209,550,623	12,235,405
18	Netick	1932	154		81,822	
19	Oficina	1937	4,500	*x*	2,542,619	2,347,625
20	Orocual	1933	2,000	*x*	29,528	0
21	Pedernales	1933	972	*x*	5,382,254	1,904,963
22	Quiriquire	1928	14,047	*x*	150,577,521	26,581,631
23	Rio de Oro	1915	390		54,877	
24	San Joaquin	1939	*x*	*x*	39,922	39,922
25	Tarra	1916	900		38,163,052	3,934,083
26	Temblador	1936	4,468	*x*	6,006,660	3,647,867
27	Totumo	1914	1,001	*x*	149,452	0
28	Uracoa	1937	*x*	*x*	40,591	16,245
29	Urumaco	1927	100		235,989	
30	Wildcat fields: Amana, Areo, Chive, Merey, Roble, Santa Ana, Yopales				137,109	24,599
31	Total		151,533		1,886,262,443	205,430,869

[b] Footnotes to column heads and explanation of symbols are given on page 239.

The number of wells producing at the end of 1939 amounted to 2488, or 169 wells fewer than at the end of 1938; producing wells in eastern Venezuela had increased from 232 to 269, while western Venezuela had declined from 2425 to 2219. Only 30 per cent of the wells were producing on natural flow, compared with 36 per cent at the end of 1938. Of the remaining 70 per cent, on artificial lift, approximately 65 per cent were produced on the pump.

There was a marked decrease in activity in proven fields, as the number of wells drilled in 1939 amounted to 444, compared with 523 in 1938. Table 2 shows that of the 444 completions, 409 wells were completed as producers, 13 dry holes were drilled in proven fields and the remaining 22 failures were all of an exploratory nature.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1939		Reservoir Pressure, Lb. per Sq. In.[1]		Repressuring Operation[d]	Character of Oil	
				During 1939		End of 1939			Number of Wells						
	To End of 1939	During 1939	Completed to End of 1939	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1939		Gravity A.P.I. at 60° F. Weighted Average	Sulphur, Per Cent
1	x	28,7xx	1,262	24	7	390	806	0	180	626	e1,5xx	e6xx	RP	24.2	2.x
2	x	24,256	508	72		212	293		109	184	e1,2xx	e9xx		18.2	2.x
3	x	48,299	1,324	150	9	542	743		108	635	e1,5xx	e9xx		16.8	2.x
4	x	1,485	39	7		34	5		5		e1,6xx	e1,6xx		15.0	2.7x
5	x	102,740	3,133	253	16	1,178	1,847		402	1,445					
6	13,611	1,685	103	5	0	44	56	3	43	13	625	510	PM	49.5	0.1
7	x	191	210			89	70			70	500	0		32.6	Tr.
8	x	x	27			13					x	x		45.0	x
9	x	x	15			10					x	x		10.5	x
10	461	213	22	11	2	7	14		5	9	150	0		26.4	x
11	284	284	20	19	1	1	19	0	19	0	2,575	2,430		33.0	0.9
12	x	310	104	2		44	59		4	55	x	x		35.5	
13	x	126	35			12	20			20	x	x		20.5	
14	x	x	9	0	0	6	3	0	0	3	x	x		32.0	0.2
15	x	1,526	24	4		11	11		11		x	x		31.0	
16	5,177	130	20			11	5	4		5	700	25		41.0	x
17	x	6,502	400	34		303	82		33	49	x	x		20.5	1.2
18			2			2					x	x		26.8	x
19	x	x	39	37	1	6	31		31		y	y		33.5	y
20	x	0	3	0	0	3	0	0	0	0	x	x		12.5	x
21	3,816	1,152	15	0	0	5	10	0	10	0	3,200	2,2xx		21.0	2.9
22	44,071	12,190	281	14	0	131	150	0	116	34	1,260	900	RP	18.0	1.1
23			4			3					x	x			
24	x	x	4	4	0	4	0	0	0	0	x	x		38.0	x
25	x	1,325	98	6	1	33	52		5	47	x	x		28.0	
26	1,900	917	79	29	3	21	58	0	58	0	1,665	1,6xx		22.0	0.8
27	x	0	4	0	0	4	0	0	0	0	x	x		20.0	x
28	x	x	2	0	0	2	0	0	0	0	x	x		15.5	x
29	x	x	4			4					x	x		37.5	x
30	x	x	8	1	1	6	1		1		x	x		x	
31	69,320	129,291	4,665	419	25	1,953	2,488	7	738	1,750					

[1] e indicates bottom-hole pressures.

The map in Fig. 1 shows the location of all fields in Venezuela, as well as the situation of all important exploration tests.

Development in Proven Fields

Western Venezuela

Lagunillas was the scene of the greatest activity during 1939 in Venezuela. Exploitation work was principally confined to drilling the southern extension of the field and fill-in wells on land. Further productive territory was proved in the Lake and important light-gravity Eocene production was discovered in the northwestern part of the field. A number of old wells in which normal levels are depleted were worked over to produce from a shallower heavy-gravity oil horizon.

Table 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1939	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Lagunillas, La Rosa, Icotea, Eocene	Mio, Olig, Eoc	Ss,[2] H	Por	1,500	2,627	80–350	MFU	Eoc	8,747
2	Lagunillas, La Rosa and Eocene	Mio, Eoc	Ss	Por	1,600–2,700	1,900–2,950	100–350	MFU	Eoc	4,346
3	Bachaquero, Lag. La Rosa, Eocene	Mio, Eoc	Ss, H	Por	2,100–4,300	2,270–4,400	80–550	MFU	Eoc	5,399
4	Bachaquero, Lag. and La Rosa	Mio	Ss, H	Por	2,850–4,150	3,150–4,650	75–450	MFU	Eoc	5,152
5										
6	Damsite and Socorro	Mio	S, H	Por	600–1,400	650–1,500	50	AF	Mio	7,720
7	Agua Clara	Olig	S, H	Por	950	1,050	50	A	Eoc	5,576
8	El Mene series	Mio, Olig	S	Por	730	750	36	M	Eoc	4,994
9	Guanoco shale	Cre	H	Fis	1,200	1,300	40	AF	Cre	4,247
10	Agua Clara	Olig	S, H	Por	550	1,500	200	AF	Eoc	4,614
11	*y*	*y*	S	Por	3,500	4,200	40	AM	*x*	5,291
12	Ramillete, Punta Gorda	Eoc	Ss-H	Por	200–2,800	950–3,800	200	AF	Eoc	5,786
13	La Paz series	Eoc	S, LS	Por	400–1,400	500–2,200	125	AF	Cre	2,290
14	Patiecitos	Olig	S	Por	*x*	2,750	*x*	AF	Eoc	5,*xxx*
15	Sandy shale formation, Mirador	Eoc	H, S	Por	3,475–4,150	3,550–4,300	400	AF	Eoc	6,260
16	Agua Clara	Olig	S, H	Por	2,200	3,000	200	AF	Eoc	5,285
17	Younger Tertiary Pauji shale and Misoa Trujillo	Mio, Eoc	Ss, S	Por	396–4,623	443–5,100	800	AF	Misoa-Trujillo	6,461
18	Eocene	Eoc	S	Por	5,860	6,097	*y*	AF	Eoc	6,097
19	Oficina formation	Mio	S	Por	4,000	6,100	40–300	AF	Cre	6,343
20	Orocual	Pli	Ss	Por	2,700	3,000	*x*	*x*	Mio-Olig	5,021
21	Pedernales	Mio	Ss	Por	5,000	6,000	*x*	AF	Mio	7,853
22	Quiriquire	Pli	Ss	Por	2,000	3,000	500–800	MULC	Mio-Olig	8,285
23	Third Coal Horizon	Eoc	S	Por	1,352	1,627	60	A	Third coal horizon	3,105
24	*x*	Mio	S	Por	*x*	*x*	*x*	*x*	Mio	7,479
25	Sandy shales Mirador Third coal horizon	Eoc	S, H	Por	1,200	795–4,500	800	AF	CreU	7,769
26	Oficina	Mio	Ss	Por	3,875	4,000	40	MF	Mio-Olig	5,492
27	Totumo horizon	Pre-Mio	Brecc Ign	Fis	2,2*xx*	2,360	*x*	MF	Pre-Mio	2,4*xx*
28	Oficina	Mio	Ss	Por	4,200	4,350	*x*	MF	Mio-Olig	5,061
29	Urumaco and Socorro	Mio	Ss	Por	4,200	4,350	60	MF	Mio-Olig	6,194
30										
31										

[2] Ss indicates soft sand.

Tia Juana, the second most active field in Venezuela, had 72 completions compared with 171 in 1938. The majority of the wells were drilled in the Lake, where further light-gravity productive territory was discovered and proven acreage increased from 15,881 acres at the end of 1938 to 18,101 at the end of 1939.

In the La Rosa area, which includes Ambrosio and Punta Benitez, 24 producers were drilled, compared with 46 in the previous year. Operations were confined mainly to Punta Benitez and 8850 acres of additional territory were proved up during the year. Repressuring work was curtailed somewhat owing to adverse results obtained.

Drilling was discontinued in the Bachaquero field early in 1939 after seven wells had been completed. Proven acreage was increased by nearly 4000 acres. It is anticipated that active development work will be undertaken in this field during 1940 along the shore-line concessions. The three operating companies in this field, as in all Maracaibo Lake fields, are the Lago Petroleum Corporation, Mene Grande Oil Co. and the Venezuelan Oil Concessions, Ltd.

TABLE 2.—*Summary of Drilling Operations in Venezuela*

Important Wildcats Drilled in 1939

	State	Coordinates			Total Depth, Ft.	Surface Formation
		North	East	Reference Point		
1	Anzoategui	124,465	457,712	Barcelona Church is N. 300,000 E. 500,000	5,243	Mesa
2	Anzoategui	134,658	627,816		3,602	Mesa
3	Anzoategui	108,048	497,400		2,872	Mesa
4	Anzoategui	112,636	468,275		2,884	Mesa
5	Anzoategui	111,560	504,412		2,843	Mesa
6	Anzoategui	96,464	452,765		1,070	Recent
7	Delta Amacuro	185,395	220,912	Tucupita[1]	4,288	Recent
8	Falcón	198,278	224,938	La Vela[1]	3,023	Recent
19	Guarico	124,150	402,950	Barcelona Church	3,728	Recent
10	Guarico	125,678	302,833		3,270	Pleistocene
11	Guarico	93,669	397,958		1,430	Recent
12	Guarico	96,698	398,646		1,392	Recent
13	Monagas	133,620	258,400	Maturin[1]	8,282	Mesa
14	Monagas	104,480	290,005	Maturin[1]	2,948	Mesa
15	Monagas	141,919	657,138	Barcelona Church	3,700	Mesa
16	Monagas	145,919	654,138		3,866	Mesa
17	Monagas	151,951	708,886		3,413	Mesa
18	Táchira	−331,447	− 78,142	Maracaibo Cathedral origin is 0-0	3,701	Cretaceous
19	Zulia	− 93,150	63,999		7,930	Recent
20	Trujillo	−120,150	88,700		10,302	Recent
21	Zulia	− 28,545	53,319		8,810	Eocene
22	Zulia	−215,853	−100,017		8,610	Eocene
23	Zulia	−233,376	−104,197		2,686	Cretaceous
24	Zulia	1,310	− 9,291		8,383	Eocene
25	Zulia	1,640	− 4,534		3,906	Eocene

[1] Origin is: N. 200,000, E. 200,000.

In spite of reduced activity in the Mene Grande field, production was maintained at the same level as in 1938; 34 wells were completed as compared with 51 in 1938. Three deep tests were drilled, but only one of these encountered oil in small quantities. This is the oldest field in Venezuela and has produced 11.1 per cent of the total oil recovered to date, but its present proportion is only 5.9 per cent.

In the Colon district, southwest of Maracaibo Lake, 10 wells were completed; 6 in the Tarra field and 4 at Los Manueles. The latter field showed an increase of more than 350,000 bbl. over the year, while Tarra also showed a slight gain. A deep test is now in progress to ascertain the possibilities of obtaining Cretaceous production in this Eocene field.

Drilling was recommenced in La Concepcion field and at the end of the year a deep test was being drilled. Production in this field, as well as in its neighboring field, La Paz, declined somewhat during the year.

El Mene, Media and Las Palmas, in the northeastern part of the Maracaibo Lake Basin, continued to show a decline in production, and the only drilling in this area was confined to the Hombre Pintado field, where 11 producers were completed and production increased from 134,035 bbl. in 1938 to 494,743 bbl. in 1939. All the oil recovered from these fields is pumped through the British Controlled Oilfields Ltd. pipe line to Altagracia on Maracaibo Lake.

Although only five wells were completed in the Cumarebo field, production increased 286,844 bbl. over the preceding year. The productive limits of this field have now been defined, and the one exploratory well

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1939

	Deepest Horizon Tested	Drilled by	Initial Production or Results		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Cretaceous	Socony-Vacuum Oil Co.	Dry	Abandoned	Carrizal No. 1
2	Miocene	Ven. Oil Dev. Co. Ltd.	Hvy. Tar	Abandoned. Non-commercial	Cerro Negro No. 4
3	Cretaceous	Standard Oil Co. Ven.	Dry	Abandoned	Hato Viejo No. 1
4	Cretaceous	Socony-Vacuum Oil Co.	Dry	Abandoned	San Diego No. 1
5	Cretaceous	Standard Oil Co. Ven.	Abandoned		Santa Clara No. 1
6	Mio-Olig.	Socony-Vacuum Oil Co.	Abandoned		Suata No. 3
7	Cretaceous	Standard Oil Co. Ven.	Abandoned		Indios No. 1
8	Mio-Olig.	Standard Oil Co. Ven.	Abandoned		Quiragua No. 1
9	*y*	Socony-Vacuum Oil Co.	Abandoned		Altamira No. 1
10	Pre-Cretaceous	Caracas Petroleum	Shows asphalt: not tested		El Machete No. 1
11	*y*	Socony-Vacuum Oil Co.	Abandoned		Iguana No. 1
12	*y*	Socony-Vacuum Oil Co.	Abandoned		Iguana No. 2
13	Cretaceous	Standard Oil Co. Ven.	Dry	Abandoned	Aceital No. 1
14	Miocene	Standard Oil Co. Ven.	Dry	Abandoned	Camorra No. 1
15	Cretaceous	Ven. Oil Dev. Co. Ltd.	Hvy. tar	Noncommercial. Abandoned	Cerro Negro No. 1
16	Cretaceous	Ven. Oil Dev. Co. Ltd.	Hvy. tar	Noncommercial. Abandoned	Cerro Negro No. 2
17	Cretaceous	Ven. Oil Dev. Co. Ltd.	Hvy. tar	Noncommercial. Abandoned	Cerro Negro No. 3
18	Cretaceous	Ven. Oil Dev. Co. Ltd.	Dry	Abandoned	Alquitrana No. 1
19	Miocene	Caribbean Petr. Co.	Dry	Abandoned	Mene Grande (MG-386)
20	Eocene	Lago Petr. Corp.	Dry	Abandoned	Motatan No. 1
21	*y*	Ven. Oil Conc. Ltd.	In progress		Pica-Pica No. 1
22	Cretaceous	Colon Develop. Co. Ltd.	In progress		Tarra (T-99)
23	Cretaceous	Colon Develop. Co. Ltd.	Dry	Abandoned	San Miguel No. 1
24	Eocene	Ven. Oil Conc. Ltd.	Dry	Abandoned	Sibucara No. 3
25	Eocene	Ven. Oil Conc. Ltd.	Dry	Abandoned	Sibucara No. 4

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1939	41	8
Number of oil wells completed during 1939	406	
Number of gas wells completed during 1939	3	
Number of dry holes completed during 1939	13	22

drilled to the southwest of the field proved a failure. Gas is still being returned to the reservoir for pressure maintenance, with excellent results, owing to favorable structural conditions. This field has the largest recovery per acre in Venezuela and yields crude of the lightest gravity, which now averages 49.5° A.P.I.

Eastern Venezuela

The Quiriquire field produced 76 per cent of the total production of eastern Venezuela, yielding over 26½ million barrels, which is a slight increase over last year's total. During the first half of the year, 14 new wells were brought into production, after which drilling was temporarily discontinued. Repressuring work for pressure maintenance is still being continued in this field.

Six strings were operated in the Oficina field throughout 1939, resulting in the completion of 37 producers and one failure. This field, the most active in eastern Venezuela, was placed on a shipping basis at the end of 1939, but the earlier completion of large storage facilities enabled the Mene Grande Oil Co. to produce 2,347,625 bbl. During December production averaged slightly more than 25,000 bbl. daily. There are many sands, which range in gravity from 17° to 40° A.P.I., and in some instances two of the sands are produced in the same well.

Temblador was the second most active drilling field, with 29 producers completed. Three failures were registered, and confirmed the fact that production can be expected only from a narrow strip extending some 30 km. This field commenced shipping oil early in 1938 and production was increased from 2,295,143 bbl. to 3,647,867 bbl. in 1939.

Jusepin crude was first shipped from Caripito in November. During the year 19 wells were completed, only one of which was a failure.

TABLE 3.—*Percentage of Total Venezuelan Production from Major Fields*

Field	Year						To Date
	1934	1935	1936	1937	1938	1939	
La Rosa	16.9	14.5	13.7	13.8	13.7	12.0	19.3
Tia Juana				14.1	23.4	23.7	6.3
Lagunillas	53.1	54.5	55.4	45.2	35.3	34.4	47.1
Total Lake fields	69.9	69.1	69.1	73.1	72.9	71.8	73.0
Mene Grande	11.0	10.4	10.0	7.7	6.6	5.9	11.1
Quiriquire	10.1	13.3	14.9	13	13.2	12.9	8.0
Tarra	2.7	2.7	2.2	1.7	2.0	1.9	2.0
Cumarebo	2.8	2.0	1.8	1.4	1.3	1.3	1.3
Temblador					1.2	1.8	0.3
Oficina					0.1	1.1	0.1
Others	3.5	2.5	1.9	2.1	3.4	3.3	4.2

This new field has produced half a million barrels of 33° A.P.I. gravity crude to date.

No further drilling was undertaken at Pedernales, but the 10 flowing wells were able to maintain production at the same level as in 1938 and showed the largest recovery per well in Venezuela.

Exploration Work

The reduction of drilling in proven fields was offset to some extent by the greatly increased amount of exploratory work done in 1939, which surpassed that of any previous year. Although no new fields were discovered, considerable geological knowledge was obtained, which should help future work of this nature. Table 2 shows the most important wildcat wells drilled during the year.

In western Venezuela, in addition to the wildcats listed, a number of outstepping wells were drilled in producing fields, which extended the proven territory at Punta Benitez and Tia Juana. Two failures were

Table 4.—*Exports of Crude Oil, Venezuela*

Field	Barrels Exported		
	In 1937	In 1938	In 1939
La Rosa	20,914,111	41,681,487	50,097,259
Tia Juana	24,931,934	25,872,473	23,963,264
Lagunillas	81,376,237	65,136,018	69,277,362
Bachaquero		637,854	3,036,263
Total Bolivar coastal fields	127,222,282	133,327,832	146,374,148
El Mene, Media, Hombre Pintado and Las Palmas	680,203	551,579	822,371
La Concepcion	1,034,340	844,493	842,669
La Paz	256,021	793,686	554,398
Mene Grande	10,142,946	7,768,101	10,625,158
Tarra and Los Manueles	4,215,269	5,057,804	5,433,386
Total from Maracaibo Lake	143,551,061	148,343,495	164,652,130
Cumarebo (Central Venezuela)	2,552,097	2,600,567	2,659,314
Pedernales	1,155,547	1,830,276	1,934,484
Quiriquire	23,959,215	24,122,867	23,352,197
Temblador		1,912,304	3,084,281
Oficina			875,066
Jusepin			333,272
Total Eastern Venezuela	25,114,762	27,865,447	29,579,300
Grand total, Venezuela	171,217,920	178,809,509	196,890,744

registered at Sibucara, near Maracaibo, one at Alquitrana in Táchira and another in the Colon district near the Colombian boundary. Motatan No. 1 created a record for deep drilling in Venezuela, but was abandoned as a dry hole after reaching 10,302 feet.

An extensive wildcatting program is still in progress in eastern Venezuela. Six exploration tests were completed in Anzoategui, five in Monagas, four in Guárico and one in the Delta Amacuro, with negative results. At the end of the year, in addition to tests being drilled at El Roble and Santa Ana by the Standard and Gulf companies, respectively, the Texas Company had bottomed Caritos No. 1 at 7098 ft. in Monagas and was drilling on Rincon 1 at 7980 ft. The Socony Vacuum was drilling Pariaguan 1 and Guario 1 in Anzoategui. Guayabo No. 2, in central Guárico, was drilling at 6219 ft. by the Guárico Oilfields (Venezuela) Ltd., and a shallow test was also being drilled on the Island of Cubagua on the northern coast of Venezuela.

In Central Venezuela a failure was recorded by the Standard of Venezuela on Quiragua No. 1, immediately southwest of the Cumarebo field.

EXPORTS

Shipments of crude oil during 1939 increased more than 10 per cent over those of 1938. Table 4 shows comparative exports from the various shipping fields for the past three years. Almost all fields register gains. Quiriquire, Tia Juana, and shipments of La Concepcion and La Paz crude from Punta Piedras near Maracaibo dropped off slightly. The Oficina and Jusepin fields commenced shipping oil during the past year, while Bachaquero and Temblador were on a shipping basis for a complete year for the first time.

Lake Maracaibo exports registered an increase of over 16 million barrels, while eastern Venezuela showed an increase of nearly 2 million barrels. Total exports amounted to 196,890,744 bbl., an all-time record for Venezuela.

REFINERIES

The throughput capacity of refineries in Venezuela was more than doubled during the past year. The Caribbean Petroleum Co. completed a new still at San Lorenzo and increased capacity of this refinery to handle a crude throughput of 28,000 bbl. per day. At Caripito, in November, the Standard Oil Company of Venezuela completed the erection of a new Visbreaker cracking plant, which has a throughput capacity of 31,000 bbl. daily. The Cia. Petroleo Lago also erected an additional still, capable of treating 5000 bbl. of light crude daily, at its La Salina refinery. On completion of the latter unit the old topping plant at La Arriaga, Maracaibo, was taken out of commission.

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Chapter V. Refining

Review of Refinery Engineering for 1939

By Walter Miller,* Member A.I.M.E.

(New York Meeting, February 1940)

The focus of attention during 1939 was on increasing the octane number of gasoline. The "octane race" resumed full swing. The average octane number of house-brand gasoline by the end of the year had easily reached two numbers higher, with several companies in the field actually purveying house-brand gasoline of 78-80 "research" octane number, equivalent roughly to from 74 to 77 A.S.T.M. octane rating, compared with the 70 A.S.T.M. ceiling of two or more years ago.

Whether this trend toward much higher octanes is the result or the cause of the many technical developments in the motor-fuel field of recent years, progress has really been startling. In addition to the advance in catalytic cracking and catalytic re-forming, other important contributions to the technical ability to produce higher octane values include: installations involving increased capacity in thermal re-forming, with improved economic status both as to yields and octane number, by coupling with catalytic polymerization; more widespread adoption of catalytic and thermal polymerization, and a surge toward extensive installations of newly developed alkylation processes for making iso-octane, neo-hexane and other high antiknock products; and greater use of improved desulphurization processes, and application of superfractionation methods for segregation of practically pure hydrocarbons with superior octane qualities from gas and highly volatile liquids.

The approaching of practical limits in the use of tetraethyl lead (the well-known "law of diminishing returns" coming into the picture at the higher octane levels being approached) has given impetus to development of the methods listed above. In particular, processes that improve the octane rating and also increase ethyl lead sensitivity have had considerable study during the year.

Catalytic Re-forming

Although the interesting report on the Houdry catalytic cracking process presented at the annual meeting of the American Petroleum

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Institute in 1938 did not mention the possibilities of catalytic re-forming of low-octane gasolines and naphthas to high octane, one of the rival groups fostering catalytic cracking announced in the early half of 1939 its readiness to build catalytic re-forming units. At this year's annual A.P.I. meeting the Houdry group announced and described a method of catalytic re-forming developed by them, and stated that prompt installation of a total of 25,000 bbl. daily capacity was to be made in this country and abroad. A 7000-bbl. unit to be installed by the rival group mentioned above has been announced for the large Texas City plant of the Pan American Refining Co. Conversion of equipment previously used for hydrogenation by the Standard of New Jersey at its Bayway, N. J., refinery to "hydroforming," the name by which this other re-forming method is known, has almost been completed. Projects for hydroforming installations by various companies, totaling another 25,000 bbl. or more, are under active consideration. Products highly sensitive to lead, with good road performance and availability for finishing to aviation gasoline, are some of the advantages claimed for catalytic re-forming over the older methods.

The program for building $35,000,000 worth of catalytic cracking plants, announced last year by Socony-Vacuum and Sun Oil, each part owner of the Houdry process, is going along at a good pace and probably will be completed in 1940. No additional commercial installations of the process have been announced by these companies, nor have any actual or proposed installations of other catalytic cracking methods been made known. The greater general interest apparently is with catalytic re-forming for the present.

POLYMERIZATION

Thermal polymerization continues to be practical only on a comparatively large scale with a cheap supply of raw material available in the form of propane and butane, with little constructional activity evinced. Catalytic polymerization, after earlier experience proved its practicability and profitableness in small as well as large units, was installed in many refineries. Something over 50 units, most of them of the catalytic type, are carrying on polymerization operations today. Catalytic polymerization lends itself particularly well to combination with re-forming, adding several per cent to the liquid yield and increasing the octane gain, but is not applicable to catalytic reforming because of the leanness of the gas produced by the latter, hydrogen predominating.

ALKYLATION

Extensive application of "alkylation," the combination of an unsaturated with a saturated petroleum-gas molecule to form a fully saturated liquid compound, was one of the outstanding developments of the year.

Some incidental alkylation undoubtedly takes place in thermal polymerization operations, but the desirability of producing such highly efficient antiknocking hydrocarbons as the neo-hexane announced commercially by Phillips Petroleum Co., as well as iso-heptane and iso-octane, has led to the development of both thermal and catalytic processes in which alkylation is the principal rather than incidental feature. Pressures of 4000 to 5000 lb. are used in thermal alkylation, and the catalytic action of 98 per cent sulphuric acid at comparatively low temperatures and pressures upon preferably closely fractionated compounds of the types to be alkylated brings about the desired result along that route. It has been largely the octane needs of aviation and the higher prices it could afford to pay for high-octane material that has spurred much of the foregoing development, but increasing application to motor gasoline is indicated in some of the predictions of rapidly rising octane ratings for automobile fuel. These bring to mind the statement frequently heard that the needs of this year's airplane motor become the requirement of next year's automobile motor. Although not literally true, it is frequently close enough to actual development for the refinery executive and engineer to keep in mind at all times.

Catalytic dehydrogenation for the preparation of unsaturated material from saturated gaseous hydrocarbons as a step in the production of iso-octane, long investigated and experimented with, flowered into approaching commercial status. Universal Oil Products Co. announced in a paper at the A.P.I. meeting that construction was starting on three plants with a combined charging capacity of 3000 bbl. per day from which will ultimately result 2200 bbl. per day of iso-octane, according to the statement.

DESULPHURIZATION

The foregoing processes generally have to do with increasing the antiknock quality of motor or aviation fuels through the manufacture of products having an intrinsically high octane rating. Reasonably high response to addition of tetraethyl lead exhibited by some of these newer products stimulated increased interest in increasing the lead sensitivity of fuels otherwise unsatisfactory in this respect. The high sulphur content of many gasolines adversely affected both the octane number and the responsiveness to tetraethyl lead addition. The difficulty and expense of adequately reducing the high sulphur content of a considerable proportion of the gasoline produced in various parts of the country have been a deterrent. The low-temperature, quick-contact sulphuric acid treatment embodied in the Stratcold process has gone through considerable improvement, resulting in lower installation and operating costs, as a result of the experience of the last two or three years, and is now in use to the extent of 90,000 bbl. of daily charging capacity. Catalytic re-forming will also play a part in the desulphurizing picture, as excessive sulphur is easily removed by catalytic treatment. In situations where octane improvement by re-forming is needed in addition to sulphur removal, catalytic re-forming seems to offer a good solution, since even cracked naphtha can be so treated under some conditions to advantage.

Other methods of desulphurization include the Houdry vapor-phase treating process, included as part of the 1938 A.P.I. paper on the Houdry process, in which gasoline vapors are passed over catalysts of acid-treated clays containing oxides of the heavier metals, manganese and nickel; and a process described by Schultz and Alden at the 1939 A.P.I. meeting, involving the bringing of vaporized oil into contact with a bauxite catalyst at temperatures of 700° to 750°F.

Use of "bottled gas"—liquefied propane, butane, pentane and mixtures—continued to expand with the effect of justifying more refinery and casinghead plants in providing equipment for segregating and making these products available. The expansion of use in automotive engines was not as great as it would have been had the distribution problem been as well worked out in other states as in California. The necessity for carrying refills of the fuel, or maintaining their own depots of bottled gas supplies, limited the increased applications chiefly to the larger trucking companies. Interesting also is the fact that the combustion qualities of the fuel show a decided advantage in providing smoother engine operations at high loads in heavy-duty oil-well drilling engines, in their activities for making more petroleum products available.

DIESEL FUEL

The continual increase of high-speed Diesel-engine applications in various fields as heavy-duty prime movers is swelling the demand for suitable fuels each year. Lack of uniformity in specifications and quality, still a serious question despite some worth-while efforts toward standardization, bedevils the refiner in attempting to supply a product that will cover a wide field and have broad acceptance. The trend in quality was toward a more closely fractionated fuel approaching kerosene in characteristics and having the special requirement of adequate cetane number and a degree of lubricating value, as well as being completely free of foreign matter that would abrade the closely fitting fuel pump. Far from being a low-cost by-product, such Diesel fuel is a material requiring extreme care in selection and refining, involving appreciable manufacturing costs.

Additions of chemical agents designed to increase detonation of Diesel fuel were studied in the effort to improve the operating chacteristics of less satisfactory fuels, but the high price of the available "dopes" limits their use. Another factor affecting the cost of Diesel fuels is the action of many state legislatures in placing a tax on Diesel fuel used in automotive equipment. This movement has gained momentum to such a degree that fewer than ten states today do not tax Diesel fuel in some way or other, thereby reducing its price advantage over gasoline.

LUBRICANTS

From the standpoint of new progress in manufacture of lubricating oil, 1939 offers little of note. Solvent refining installations totaling about 10,000 bbl. daily capacity were made during the year, and a competent authority estimates that the various solvent-treating installations in this country now approximate 70,000 bbl. daily capacity. This figure must come fairly close to the saturation point. In few plants is solvent-treating yet to be adopted or existing installations augmented. (The same authority estimates approximately 32,000 bbl. of capacity installed in countries outside of the United States, giving a round figure of 100,000 bbl. of total daily capacity for the world.)

Use of additives to improve characteristics of lubricating oil was more widespread in the common effort to solve the problems of oxidation of motor oil and the troublesome "lacquering" of engine parts that has developed with the increasing temperatures and speeds, and the closer clearances of the modern automobile engine. The problems were by no means solved, but progress was made.

WAX

No solvent-dewaxing installations of any size were reported. The rather significant drop in wax production from 1937 to 1938 of about 86,000,000 lb., or 16 per cent, stayed in effect through 1939, this year's production holding approximately even with 1938. This lends support to the hypothesis that the replacement of the older dewaxing equipment by solvent dewaxing has to an extent involved diverting the wax into charging stock for cracking stills instead of permitting it to be finished into paraffin wax. Although apparently the lower rate of production during 1938 was almost sufficient to take care of the demand, stocks decreasing about 16,000,000 lb.—export increases of between 40,000,000 to 50,000,000 during 1939, in the face of only a small increase in production, effecting over 50 per cent decrease in stocks—brought about an unusual rise in prices and made current wax production more profitable than for years.

DEVELOPMENTS IN USE OF PETROLEUM

As a raw material for chemical manufacture, petroleum continues to gain greater interest. The most outstanding commercial development was the completion of an ethyl chloride manufacturing plant by the Ethyl Gasoline Corporation at Baton Rouge, La., utilizing refinery gases from the Standard of Louisiana plant and yielding a base material for use in preparing tetraethyl lead. Also important was the installation of an ethylene glycol manufacturing plant by the duPont interests in West Virginia. Possibly a new chemical field was opened in another direction by development of nitration as applied to petroleum hydrocarbons by the Commercial Solvents Corporation.

Great general interest has been shown also in learning more about the components of petroleum, marked by active work on the A.P.I. hydrocarbon research project at Ohio State University, begun in 1938 for the purpose of preparing gasoline-range hydrocarbons and examining them for engine-combustion characteristics and physical and thermal properties. This research complements work being done by the National Bureau of Standards and numerous other laboratories, public and private. Results are expected to have commercial application, probably leading to the segregation of hydrocarbons with desirable characteristics for such purposes as motor fuels, chemical raw materials, and solvents.

Important to the refining industry was a U. S. District Court decision, a decision that has been accepted without an appeal hearing, holding that the Gray process patents for vapor-phase clay treating are valid. In another interesting case a U. S. Circuit Court of Appeals ruled after a second rehearing that a patent on auxiliary or "sidestripper" bubble towers is invalid. Unless the Supreme Court on appeal should reverse this decision, such auxiliary towers can be freely used by the industry.

Certainly 1939 was an internal-combustion-motor-fuel year with emphasis along automobile and aviation lines, with decided improvements increasing antiknock quality.

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- Johnson, O. W. and Pollard, T. A.: *Air Conditioning as Applied to Oil-field Buildings in Tropical Climates, Heating and Ventilating*, Sept. 1939.
- Johnston, N.: *Discussions: on Effect of Temperature on Plastering Properties and Viscosity of Rotary Drilling Muds*, 172
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- Kline, M.: *Subsurface Trespass.* Pub. by Amer. Bar Assn., Section of Mineral Law.
- Knight, E. T. and Gill, J. D.: *Place of the Oil Industry in the National Economy, Bull.* Robert Morris Associates, April 1940; also *Min. and Met.*, Aug. 1940.

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